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THE ROLE OF UNDERSTANDING IN THE PHILOSOPHICAL WRITINGS OF NIELS BOHR:

A Place for Hermeneutics in the Natural Sciences

by

LISA M. DOLLING

A dissertation submitted to the Graduate Faculty in Philosophy in partial fulfillment of the requirements for the degree of Doctor of Philosophy, The City University of New York

1995

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Abstract

THE ROLE OF UNDERSTANDING IN THE PHILOSOPHICAL WRITINGS OF NIELS BOHR:

A Place for Hermeneutics in the Natural Sciences

by

Lisa M. Dolling

Advisor: Professor Marx W. Wartofsky

In this work I look at the Copenhagen interpretation of quantum physics, especially as espoused by Niels Bohr, and place it in the context of the so-called "interpretive-turn" contemporary philosophy has taken. From a close reading of the three volumes of philosophical essays written by Bohr, I show how the philosophy that emerges as the result of heeding a variety of what Bohr refers to as "epistemological lessons" is quite consistent with a philosophical hermeneutics one finds in the work of Hans-Georg Gadamer.

Principally, I show how the three central aspects of Gadamer's thought, namely, Dialogue, Experience, and Bildung (Culture), are likewise at the heart of the thought of Bohr.

After a brief history of hermeneutics, including the understanding/explanation dichotomy as it plays a role in the philosophy of science, I examine the following topics: a) A brief history of quantum theory; b) The measurement

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problem and the subject-object distinction; c) Language and objectivity; d) The problem of causality and the breakdown of language; e) Realism and truth; f) Complementarity

My analysis shows similarities between the way Bohr treats these scientific/philosophical issues and the treatment they are given by Gadamer and modern hermeneutics.

Most importantly, I show how Bohr's innovative (and oftentimes puzzling) conception of "Complementarity" belongs to philosophical hermeneutics just as much as to quantum theory. Bohr's attempts to apply complementarity outside the domain of physical science--especially to ethnological and anthropological studies--yield an approach to these disciplines that is similar to the more hermeneutic approach found in the work of Peter Winch and Clifford Geertz.

Finally, I show how Bohr's attempts to propound a theory of a "Unity of Knowledge" contribute to the current rationality debates taking place in the philosophy of science and are further evidence that we have moved <u>beyond</u> the more traditional exclusionary choices of "realism versus anti-realism" and "objectivism versus relativism."

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PREFACE AND ACKNOWLEDGEMENTS

I first encountered the thought of Hans-Georg Gadamer while a graduate student at Fordham University. For a graduate seminar on the "late Heidegger," I had chosen to write a paper on the essay "The Origin of the Work of Art." The seminar director, John D. Caputo, naturally suggested I look at Gadamer's exposition of Heidegger's essay. It was from that moment that I knew what my philosophical position would be. My intuitions always led me toward the position of a universal hermeneutic--namely that interpretation is a universal and ubiquitous feature of all human activity, in a Gadamerian sense, and that all interpretation always takes place within some context or background, whether it be a web of belief, complex social relation, tradition, etc. The key is to maintain this position while avoiding the pitfall of relativism.

Shortly thereafter, I became acquainted with the work of Thomas Kuhn and the so-called "post-empiricist" philosophy of science. I saw in this philosophy an implicit hermeneutic theory. Much to my delight I learned that I was not alone in seeing this common thread. In fact Kuhn himself waxes poetic about his discovery of hermeneutics and the hermeneutic circle and how it confirmed his philosophical leanings, despite the fact that the word "hermeneutics" was not even in his

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vocabulary as late as 1972[1], a decade after the publication of his major work.[2]

The desire to combine my interests in both hermeneutics and the philosophy of science led me to the work of Niels Bohr. The more I read Bohr's philosophical essays, the more I realized that I had found the link between these two fields of study. I found implicit in Bohr's thought a hermeneutic theory in its own right, especially regarding the emphasis Bohr places on dialogue and language in the development of scientific theory.

While the thought of Bohr, especially his notion of "complementarity," remains ever puzzling and elusive, I can only hope that I have contributed to the effort to understand it. In addition, I hope I have been able to contribute to the dialogue regarding the interpretive nature of the natural sciences in general, and given evidence for the indispensability of both hermeneutics and the thought of Gadamer.

I would like to give special thanks to those who have given me moral, intellectual, and emotional support throughout not only the writing of this dissertation, but through my philosophical development in general.

First of all I would like to give special thanks and love

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[1] See especially Thomas Kuhn, The Essential Tension (Chicago: University of Chicago Press, 1977).

[2] Thomas Kuhn, The Structure of Scientific Revolutions (Chicago: University of Chicago Press, 1962).

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to Mary T. Clark, R.S.C.J., and Raymond Langley for introducing me to the wonderful world of philosophy 15 years ago. Their support, encouragement, and love throughout the years has meant more than they will ever know.

I would also like to give special thanks to my illustrious mentor, Marx Wartofsky, for his invaluable assistance through the writing of this work. I thank him not merely for his brilliant ideas and suggestions along the way, but perhaps most importantly, for the faith and confidence he always expressed in my capabilities. I am truly fortunate in having had the chance to work with not only such a fine scholar, but a wonderful man as well.

I would like to thank my committee, Martin Tamny and John Greenwood, for their support and encouragement from the moment that I had the idea for this project, and my readers Frank Kirkland and Joan Stambaugh, especially for making my defense so enjoyable!

As I leave The City University of New York, I am fortunate in being able to look back with fondness on the past 6 years and would like to extend special thanks to Arthur Collins for giving me the opportunity to resume my graduate studies and finish my Doctorate there. Thanks to the current executive officer, Richard Mendelsohn, especially for withstanding my occasional breakdowns (!) and love and thanks to Rosemarie Iannuzzi for being such a wonderful friend.

I would also like to give special thanks to those

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Professors I had the honor of working with while at Fordham University, especially W. Norris Clarke, S.J., Elizabeth Kraus, and especially Dominic Balestra, for his special interest in my work and progress.

While it goes without saying that nothing of great measure can be done without the love and support of family and friends, there are a few whose encouragement through the writing of this work deserve special mention: Mark Burke, Nicholas Tirone, Karin Brown, and Alina Hunt--all for putting up with an incoherent, oftentimes absent friend, as well as for having such inspiring confidence in me. Thanks also to Sue Weinberg for her encouragement and praise, and for always knowing the right thing to say!

Special thanks to my parents, Mari and George Dolling, without whom nothing would be either possible, or worthwhile.

Lastly, and indeed most importantly, to my husband Peter Muccio, more love, thanks, and appreciation than words can possibly express. I could not possibly have achieved this dream without him.

I would like to dedicate this work to Peter, someone (if he will allow me one last appeal to Aristotle!) "whom bad men have not even the right to praise, and who shows in his life how to be happy and good at the same time."

LMD, 1995

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"Niels Bohr was primarily a philosopher, not a physicist."[1]

-Werner Heisenberg

[1] "Quantum Theory and Its Interpretation" in S. Rozental ed., Niels Bohr: His Life and Works as Seen by his Friends and Colleagues (New York: North-Holland, 1985), p. 95.

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I. Introduction

Most physicists maintain that the Copenhagen interpretation of quantum physics as formulated by Niels Bohr is the most comprehensive and consistent articulation of physical theory at the quantum level.[2] For Bohr, however, the philosophical theory implicit in the physics was no less important. In fact, Bohr maintained that in his dealing with quantum phenomena were contained a variety of "epistemological lessons" that philosophy would benefit from. It is the aim of the present study to work out the kind of philosophy that emerges from heeding those lessons. What we shall see is that when we fulfill Bohr's wishes and extend the epistemological lessons that quantum theory teaches us to all fields of inquiry, what we get is a philosophical approach that bears a striking resemblance to the kind of philosophical hermeneutics one finds in the thought of Hans-Georg Gadamer. In particular, we will see how the three central aspects of Gadamer's thought, namely, Dialogue, Experience, and Bildung (Culture), will likewise be at the center of the thought of Bohr.

What follows is a brief summary of some of the ways in

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[2] In The Conceptual Development of Quantum Mechanics (New York: McGraw-Hill, 1966), Max Jammer states, "Though not necessarily the only logically possible interpretation of quantum phenomena, it is (the Copenhagen interpretation) de facto the only existing fully articulated consistent scheme of conceptions that brings order into an otherwise chaotic cluster of facts and makes it comprehensible," p. vii.

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which the kind of philosophy Bohr espoused is consistent with both a philosophical and a universal hermeneutic, as well as a brief explanation of the kinds of lessons we encounter.

First of all, to make the claim of universal hermeneutic is to maintain the following two assertions[3], both of which are given support in Bohr's thought: First, there is what is called "hermeneutic universalism," which claims that "interpretation is a universal and ubiquitous feature of all human activity." We will see how Bohr's emphasis on the inescapability of language and its essentially metaphoric nature will lend credence to this assertion that interpretation pervades all of our activities.

Second, there is the claim of "hermeneutic contextualism" which maintains that "interpretation always takes place within some context or background" whether it be a web of belief, a tradition, or social practices. Along similar lines, Bohr will make the claim that all of our interpretation in science takes place within our linguistic/conceptual framework--while in social understanding within the framework of our cultural conventions.

Philosophical Hermeneutics places language and interpretation at the center of all of our activities. For Gadamer, the essential nature of that language which pervades

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[3] The following two strands of a "universal hermeneutic" are described in David R. Hiley, James F. Bohman, and Richard Shusterman, eds., The Interpretive Turn: Philosophy, Science, Culture (Ithaca: Cornell University Press, 1991).

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all of our activities is dialogical. Bohr too will emphasize the essentially dialogical character of understanding, especially in science. Throughout his writings, Bohr emphasizes that he conceived of the scientific enterprise as a "dialogue with nature." In that respect, our experiments become questions we put to nature in the hope of receiving an answer. In fact we will see how for both Bohr and Werner Heisenberg, the other principle advocate of the Copenhagen interpretation, one of the most significant aspects of scientific inquiry was learning to ask the right questions.[4]

Furthermore, in addition to this emphasis on language and dialogue what we shall see is that the epistemological lessons Bohr describes are oftentimes already found in a more hermeneutic philosophy. For example, the first lesson we learn in quantum physics is that the line of demarcation between subject and object can no longer firmly be drawn. As a result of the so-called "measurement problem" in quantum physics, which asserts that during any observation at the quantum level there will be an uncontrollable exchange of energy which somehow affects or "disturbs" the object of observation, one must always take into consideration the

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[4] Interestingly, this conception of science as a "dialogue with nature" has recently been emphasized by people like Evelyn Fox Keller and Helen Longino in their attempts at constructing a Feminist philosophy of science. See especially. Evelyn Fox Keller, "Feminism and Science" and Helen Longino, "Can There Be a Feminist Science?" both reprinted in Ann Garry and Marilyn Peersall, eds., Women, Knowledge and Reality: Explorations in Feminist Philosophy (Boston: Unwin Hyman, 1989).

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circumstances under which evidence was obtained. When applied to matters of interpretation, this lesson becomes an awareness of the subject in any interpretive act. That means an awareness of the historical, cultural situatedness of any act of understanding--what Gadamer calls the "horizon" of interpretation. Bohr intended that we take this lesson, gleaned from such an unlikely source as natural science, and apply to it all fields of inquiry. When we do so, what we get is the emphasis on contextualization mentioned above.

Secondly, by redefining objectivity as Bohr does as "unambiguous communication," Bohr is implicitly stating that all knowledge and truth is linguistically mediated. Likewise, emphasizing the communicative aspect of objectivity ushers in a discussion of the social dimensions of science which one finds so often in more recent, post-empiricist philosophy of science.

Finally, and perhaps most importantly, we have the lesson of "Complementarity". Bohr proposes his notion of complementarity as a solution not only for wave-particle dualism, but for any field of inquiry where there is compelling evidence for more than one, oftentimes contradictory, mode of description. For our purposes, the most interesting of applications of complementarity outside the realm of natural science will be Bohr's attempt to use it as a tool in the studying of other cultures. Bohr will make the claim that different cultures are "complementary" to each

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other, suggesting that we apply the same lesson used in solving wave-particle dualism to the understanding of a foreign society. What we shall see is that when we do so, there are striking similarities to the more hermeneutic approach to anthropological study found in people like Clifford Geertz and Peter Winch. In addition if we heed Bohr's advice and attempt to understand other cultures through the framework of complementarity, what we get is an emphasis on tolerance and solidarity that are a result of Gadamer's conception of Bildung. In all, it remains quite remarkable that Bohr shows how the openness to new experiences in physics, including a willingness to alter our theoretical assumptions and expectations, can serve as a model and prepare us for an openness to the understanding of different cultures which, Bohr will maintain, should be the aim and goal of all science.

In that respect, we will see how Bohr likens the journey into the quantum realm to the journey into a foreign culture, where we are oftentimes forced to reexamine our conceptual and cultural prejudices and be open to the possibility that things may be other than we expect. His point is to examine what it is we do when we go beyond the bounds of ordinary experience--beyond the pale, so to speak. We should examine what we do when we encounter something that is so contrary to what we are accustomed to, whether it be in the realm of the quantum, or in a foreign culture. Bohr's point will be that the lessons

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from one field of study can provide help with solutions to problems in the other.

In fact, Bohr's interpretation of quantum physics can even be shown to substantiate the claim of hermeneutics that all understanding is self-understanding in as much as he emphasizes the fact that in quantum physics as well we learn about ourselves as active participants in the world "of which we are a part." We learn about our relationship to nature, and we learn about what takes place when we attempt to make our experiences coherent and communicable.

In addition, I will locate Bohr's philosophy in the present rationality debates and show how his philosophy is consistent with the hermeneutic claim that we have gone beyond certain traditional parameters and dichotomies. I will place Bohr's interpretation of quantum theory against the background of the recent claim by Richard Bernstein that we have gone "beyond" the traditional categories of objectivism versus relativism, realism versus anti-realism, etc. In that respect, we will see how Bohr rejects not realism <u>per se</u>, but the classical version of it. His alternative will be shown to be consistent with the more hermeneutic alternative of a "metaphoric realism." Along similar lines, both Bohr and Gadamer reject not objectivity <u>per se</u>, but the classical version of it that pits objectivity against relativism. For both, objectivity will be a function of language and depend on consensus.

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Even Bohr's conception of truth will be shown to be similar to the hermeneutic notion of aletheia, which replaces truth that is representational with one that is disclosive.

Finally, while not claiming to solve the issue, we will see how such an explication of Bohr's philosophy contributes to the present debate regarding the interpretive nature of the natural sciences. Once we accept the essentially metaphoric nature of all language, philosophical and scientific alike, it can no longer be the case that there is a separate domain of sciences that are hermeneutic. Bohr understood science as a "work" of man, and as such it can be subject to the same mode of analysis as all other works. In that respect, natural science can likewise be said to be a Geisteswissenschaft. That is not to say that there do not remain fundamental differences between the natural and human sciences.[5] However, despite the claim to a universal hermeneutic, the issue of demarcation between the natural and human sciences remains unresolved. As Jarrett Leplin has stated regarding the realism versus anti-realism debate, "we need more philosophy to settle the issue."[6]

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[5] Interestingly, even Heisenberg, who often compares science to art, making the claim that the two processes are "not very different," makes the claim that science is nonetheless less forgiving in our errors. Nature immediately let's us know when we have gone astray. See especially Heisenberg's Physics and Philosophy (London: G. Allen and Unwin, 1971).

[6] See Jarrett Leplin, Scientific Realism (Berkeley: University of California Press, 1984).

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II. Hermeneutics and the Understanding/Explanation Dichotomy

Since as far back as Aristotle, the problem regarding the separation or unity of the sciences has been at issue. The question being, are there many different disciplines separable by virtue of their subject matter and warranting different methods, as Aristotle seemed to propose, or is there a unity of the sciences as Descartes would have us believe, with a universally applicable method that would allow us to attain truth unilaterally? (One need only consider the full title of Descartes' work, Discourse on the Method for Rightly Conducting One's Reason and for Seeking Truth in the Sciences, and the "Method" as given in Part II of the Discourse to elucidate the emphasis on universal method). And of course the theme of the Unity of the Sciences is cast anew in light of the emergence of positivism and neo-positivism in the 20th century.

More recently, however, as a result of the so-called "interpretive turn" in philosophy and the emphasis on the prejudices and preconceptions of the knower (webs of belief, conceptual frameworks, social practices, etc.), this issue has been reformulated in terms of the Verstehen/Erklären dichotomy. If there were a distinction to be made between the sciences, it seemed that it was by virtue of the labor being carried out in the discipline in question. If the discipline required understanding, (with its concomitant notions of

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meaning and interpretation) it was considered of a certain type, and likewise with explanation. Thus the sciences were grouped under the following headings: you had on the one hand the Geisteswissenschaften, having something to do with the human spirit or creations of man, replete with meaning and therefore requiring understanding; and on the other hand, the Naturwissenschaften, having to do with nature and therefore bereft of meaning, requiring merely explanation. The terms Geisteswissenschaften and Naturwissenschaften became the acceptable categories for such a division among the sciences, separable not only by the subject matter, but by virtue of the this division of labor between understanding and explanation. The Geisteswissenschaften[7] became known (in the English speaking world) as the "human sciences," concerned with specifically human matters and actions, lending themselves to interpretation inasmuch as they were purposeful and meaningful, whereas the Naturwissenschaften included the physical/empirical sciences, warranting merely formal explanation. Thus the very notions of meaning and interpretation became counterparts to scientific explanation.

As the debate concerning the unity of the sciences continues today the notion of "understanding" remains the focal point around which positions are argued. As far as

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[7] The first coinage of the term "Geisteswissenschaften" was by the translator of J.S. Mill's System of Logic, and was intended as the German translation of what Mill referred to as the "moral sciences."

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philosophers of science are concerned, whether or not one maintains that understanding plays a role in the activities of natural science usually determines where one stands on the demarcation issue. We have seen those with more of a positivist tincture (like Hempel, Carnap, and Nagel) try to eliminate understanding from the scientific enterprise altogether.[8] For them the aim of natural science is to provide a formal explanation of objectively verifiable events that will yield predictive power (harkening back to Bacon's equation of knowledge with power). This more empiricist view of natural science (Hempel/Nagel and co.) usually fixes the meanings of terms and posits theories as open and subject to empirical verification.[9] There is neither need nor desire for understanding so long as the facts are accounted for objectively. A desire for understanding was seen as a desire to obtain a deeper sense of a situation or event, one that could not be freed from historical or cultural concerns--and it was precisely these concerns that were considered to be obstacles to objectivity. Such is the understanding/explanation dichotomy as it plays a role in the philosophy of science.

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[8] It has been argued, however, that the seeds for a Verstehen theory can be found in Hempel and Carnap as well.

[9] Developments in problems of confirmation theory (especially Hempel) and Popperian falsification notwithstanding, the general notion is that there is a correspondence between our theories and nature that can at least be partially confirmed, pace Quine and Duhem, even if not localized.

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As for the origins of the dichotomy itself, one finds its source in a reaction to the scientific revolution. Interestingly enough, the emergence of modern hermeneutics as a discipline in and of itself shares this very same origin (discussed below). This point of departure for both the understanding/explanation dichotomy and the emergence of the discipline of hermeneutics has been described as a feeling of estrangement from the natural world that we as human thinkers and knowers feel resulting from the science of the Enlightenment. As natural science became more systematic and more formalized and mechanistic, it seemed bereft of meaning and significance for man as he no longer recognized himself in such a mechanistic world (save Hobbes of course). Where was man to turn to learn about himself? In an attempt to retrieve a sense of meaning, man turned away from Nature, (something he hasn't produced), toward that which he has produced, namely, the subject matter of the historical sciences, history being a product of man. The first systematic attempt to ground the historical sciences methodologically and distinguish them from the natural sciences using this distinction between explanation and understanding was by Johann Droysen. In his Grundrisse der Historik, (1858) Droysen writes, "According to the object and nature of human thought there are three possible scientific methods: the speculative (formulated in philosophy and theology), the mathematical or physical, and the historical. Their respective essences are to know, to

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explain, and to understand."[10] Thus the role and scope of understanding (and the concomitant notions of significance and meaning) were quite limited. Then, to add insult to injury, once neo-positivism came on the scene and attempted to make philosophy (and eventually all the human sciences) conform to the methods and rigor of the physical sciences, understanding all but dropped out of our cognitive lives. The very notion of understanding became a psychological device for the evocation of sympathy, leaving it with a purely emotional import. According to this way of thinking, we understand the genius behind a great work of art or a great work of literature when we can empathize with the spirit of the genius that created it.

The first reaction against this steamrolling by logical method begun by Mill was by Wilhelm Dilthey. Around the turn of the century, Dilthey attempted to establish Hermeneutics (understood as the science of interpretation) as the science and method for the human sciences. This is often viewed as an attempt to remedy the initial phase of what is often called the crisis of understanding. Wilhelm Dilthey and early proponents of Hermeneutics[11] tried to place "understanding"

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[10] See especially Karl-Otto Apel Understanding and Explanation, trans. Georgia Warnke (Cambridge MIT Press, 1984).

[11] We are here talking about modern hermeneutics--the discipline as initially formulated by people like Schleirmacher and Dilthey, where Hermeneutics is no longer reserved for or limited to Biblical interpretation and jurisprudence. We will discuss the origin of the term itself

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once again into the forefront by making it the aim and goal of the human sciences. As Fred Dallmayr and Thomas McCarthy note in their introduction to Understanding and Social Inquiry, "Dilthey is known as the architect of the so-called Geisteswissenschaften--a philosophical and methodological bulwark designed to stem the tide of positivist science."[12] Thus the natural sciences could maintain their claims to formal explanation as the positivists insisted, so long as they did not try to impose their methods and goals on the human sciences.

One finds this same way of thinking--namely an effort to recapture the spirit of man-- in the writings of Giambattista Vico. In his Scienza Nuova of 1744, Vico suggests that history and culture were more readily intelligible than nature since man was their author and thus could recapture himself in records of the past. In essence, Vico's point was that only that which man had created (namely history) could he effectively understand. In that respect, Dilthey's Lebensphilosophie is formulated and developed much in the spirit of Vico. In fact Richard Bernstein remarks on this similarity in spirit between Vico and Dilthey in his 1983 work Beyond Objectivism and Relativism. In Bernstein's view what changes throughout the course of the history of philosophy,

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briefly below.

[12] Fred R. Dallmayr and Thomas A. McCarthy, (eds.), Understanding and Social Inquiry (Notre Dame: University Press, 1977), p. 3.

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(including the present-day rationality debates), is not the substance of the arguments, but merely the players involved: He points out that merely "the dramatis personae change: Descartes versus Vico, Comte or Mill versus Dilthey, positivists and logical empiricists versus ordinary language philosophers and phenomenologists."[13] (One could add Einstein versus Bohr to these pairs of disputants).

Dilthey thus heralds in the birth of modern Hermeneutics as a discipline in and of itself, marking the science of interpretation. The discipline itself, however, enjoys a long history, which is summarized briefly as follows:

The roots for the word Hermeneutics lie in the Greek verb Hermeneuein, generally translated "to interpret." Etymologically the word points back to the messenger god Hermes--the wing-footed messenger god--the go-between for gods and man. Significantly, in antiquity Hermes is associated with the function of transmuting what is beyond human understanding into a form that human intelligence can grasp. Similarly, in understanding one goes from unintelligibility to understanding via interpretation; but in both cases, assistance is needed. As David Cousins Hoy claims, as the ancient world had Hermes, we need hermeneutics.[14] Furthermore, the Greeks credited Hermes with the discovery of

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[13] Richard Bernstein, Beyond Objectivism and Relativism (Philadelphia: University of Pennsylvania, 1983), p. 48.

[14] Hoy, David Couzens, The Critical Circle (Berkeley, University of California Press, 1978).

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language and writing as well. Heidegger makes this connection between the Greek dependence on Hermes and the development of hermeneutics explicit in his work On The Way to Language. There he states that Hermes "brings the message of destiny; hermeneuein is that laying open of something which brings a message, insofar as what is being exposed can become message..."[15] We see that because of its etymological roots, the task of interpretation has been to make something that is unfamiliar, distant, and obscure in meaning into something real, near, and intelligible.

In modern times, Hermeneutics takes three different forms. They are as follows:

1) First, as a result of the estrangement of man wrought by the scientific revolution (mentioned above), man could no longer look to the biblia natura for meaning. As a result, he turned from the biblia natura to the Biblia Sacra--thus Hermeneutics finds its first modern home in Biblical exegesis. Indeed this remains (outside philosophical circles) the oldest and most widespread understanding of the word. Here Hermeneutics concerned itself with the transmuting of meaning of a potentially unintelligible and ambiguous text.

2) Secondly, hermeneutics finds its way into legal studies and jurisprudence and interpretation of legal texts.

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[15] Unterwegs zur Sprache, p. 120; see Richard E. Palmer, Hermeneutics: Interpretation Theory in Schleiermacher, Dilthey, Heidegger, and Gadamer (Evanston: Northwestern Press, 1969), p. 10ff.

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3) Finally, modern hermeneutics is associated with the philosophical tradition beginning with Dilthey, and his predecessor Schleiermacher--and it is to this form that we return.

According to Dilthey, historical understanding is an operation fundamentally distinct from the quantifying, scientific grasp of the natural world, for in this act of historical understanding, what is called into play is a personal knowledge of what it means to be human. What was needed in the human sciences, Dilthey believed, was another "critique" of reason that would do for the historical understanding what Kant's Critique of Pure Reason had done for the natural sciences--thus his work is intended to be a Critique of Historical Reason.[16]

As a result of Dilthey's work understanding is once again put into the forefront by making it the aim and goal of the human sciences; and yet at the same time understanding is deprived of the natural sciences. So although we were given back (so to speak) the notion of understanding we had lost as a result of positivism, it was still denied in that aspect of our lives which was supposed to be the most fruitful when it came to knowledge. Most still considered the natural sciences to be the most successful disciplines, the paradigmatic expression of human rationality--mathematics as applied to experience. And yet at the same time we are told that our

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[16] Dilthey did not live to see this work published.

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understanding plays no role in our scientific endeavors. As even Dilthey himself has put it, "Nature we explain, psychic life we understand." So we see that in his own way, Dilthey (and early hermeneutics) promotes that self-same positivist notion of natural science. This brings about what many philosophers of science deem another "crisis of understanding"--one which estranges us from the natural world in as much as we are permitted only formal access. We are denied a deeper probing, a search for meaning that would make us feel more at home in nature. Yet, as we shall see Niels Bohr repeatedly remind us, we are indeed a part of that nature.

The mistake of people like Dilthey was that they identified understanding with psychological empathy, with the reenactment or "reproduction" of mental and emotive processes. Perceived in this fashion, it becomes logical that understanding be eliminated from objective natural science. After all, who would be so bold as to attempt to capture the spirit, or perhaps more audaciously, recreate the act of the Divine! But as I shall maintain, this elimination is founded on a fundamental mistake about the aim and function of understanding. This mistake is soon rectified within hermeneutics by the work of Hans-Georg Gadamer. In his philosophical hermeneutics Gadamer gives a reformulation of both the function of hermeneutics and the role of understanding in our lives. Foremost among Gadamer's aims in

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his conception of hermeneutics is to give the historicity of the interpreter back to him. This means an embracing of the very prejudices that those more methodologically minded thinkers like Dilthey sought to eliminate. For Dilthey, the prejudices of the interpreter, including cultural and historical situation, served as obstacles to proper interpretation. Indeed the Cartesian ideal of a prejudice-free autonomous subject was still a desideratum for the attainment of truth. And "method" was seen as the proper instrument for this "prejudice-free" subject. Method had become just as crucial for Dilthey and early hermeneutics in guarding against error in interpretation as it had been for Descartes and the scientists of the Enlightenment with regard to scientific knowledge. It is precisely this preoccupation with method that Gadamer sees as being the very obstacle to proper hermeneutics.

In his monumental work entitled Truth and Method[17] (1960), Gadamer seeks to purge hermeneutics of the taint of methodology; in fact method is seen as an impediment to a full appreciation of understanding. For Gadamer, understanding is not psychological but ontological. It is, as he claims, a primordial fact about man's being, and it is precisely the modern obsession with method that has distorted and concealed the ontological character of understanding. To say that

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[17] Hans-Georg Gadamer, Truth and Method (New York: Crossroad Publishing Co., 1986).

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understanding is ontological and primordial is to assert that it is descriptive of our situation in the world. We do not choose to seek understanding. Rather understanding is characteristic of our interaction with any text, situation, or event we encounter including the scientist's encounter with nature.[18] According to Gadamer there are then certain conditions we must articulate regarding our understanding--conditions that center around our prejudices. Gadamer understands the term prejudice in the German sense of Vorurteil--literally a pre-judging or projection of meaning. In that respect, prejudices are not necessarily all negative as one can distinguish between distorting and enabling prejudices[19]. The enabling prejudices make up what Gadamer calls our "horizon or interpretation." Understanding comes about then by a "fusion of horizons," a bringing together of past and present: our past with the present of the text; our present with the past or former interpretations--the so-called "tradition" of the text.

Gadamer will replace Method with History. The prejudices of the interpreter, including his historical situation, will be seen not as obstacles to be overcome as Dilthey conceived

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[18] Although Gadamer does not treat the natural sciences directly in Truth and Method, in order to maintain the claim that understanding is an ontological description of our being-in-the-world, it seems he must admit to events of understanding in the natural sciences as well.

[19] It is the function of dialogue and critical reflection to eliminate distortive prejudices.

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it, but rather as the very conditions for understanding, in the Kantian sense. We must realize that without such historical conditions understanding could not take place; and, as Gadamer has often noted, Truth and Method is an attempt to elucidate these conditions for understanding. In the foreword to his magnum opus he affirms that he is indeed asking a question (much the way Kant did) when he asks, "How is understanding possible? This is a question which precedes any action of understanding on the part of subjectivity..."(Truth and Method, xviii).

According to Gadamer, understanding pervades all human relations to the world. It is not just one of the various possible behaviors of the subject, but, borrowing from Heidegger, he asserts "that it is the mode of Dasein itself." (Truth and Method xviii).

It would seem prima facie that from a Gadamerian stance, there should be a unity of the sciences inasmuch as the sciences are universally hermeneutic. It would likewise seem that both a universal Hermeneutic and demarcation of the sciences are incompatible. Nevertheless attempts to collapse the distinction along lines of a universal hermeneutics usually usher in relativism and ethnocentrism and lead to extremist positions typified by people like Rorty, Feyerabend, and in an almost hyperbolic sense, Derrida.

On the other hand, there are those who seem to accept the hermeneutic situation and yet still maintain a strong

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demarcation among the sciences. These hermeneuticists usually remain cautious when discussing the natural sciences (Taylor, Apel[20], Ricoeur). Thinkers in this camp are accused (by their more liberal counterparts) of being unfaithful to their discipline and being guilty of kowtowing to a positivist conception of the natural sciences. And yet, this more positivist depiction of natural science depends on hard-drawn distinctions between theory and observation, and fact and value, which many would agree are just not borne out. In fact these distinctions are ones that very few doing the philosophy of science today would subscribe to.[21] Rather, they are indicative of the old positivist picture of science, the so-called "received-view" that has by and large been abandoned. Just what has been abandoned are old vestiges of positivism that are incompatible with the hermeneutic position. Precisely what we have moved beyond is something like the following:

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[20] While Apel is sympathetic to a universal hermeneutic and will admit that understanding does have a role in natural science, he will insist on a balancing of understanding with a complementary task of explanation. According to Apel, this correcting of understanding with explanation will serve to eliminate the possible pitfalls of historicism and subjectivism often generated by understanding alone. See especially, Understanding and Explanation.

[21] Cf. especially Mary Hesse, Revolutions and Reconstructions in the Philosophy of Science (Bloomington: University of Indiana Press, 1980) and Frederick Suppe, ed., The Structure of Scientific Theories (Urbana: University of Illinois Press, 1977), for a concise and thorough treatment of the status of "empiricist" and "post-empiricist" philosophy of science.

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On the "Received view" of science, one can separate theory from observation in the following way: all scientific language can be subdivided into theory terms and observation terms, the observation being preferable because they are subject to verification. In proper science, all theory language was to be reduced to observation terms via correspondence rules so that theories could be verified and confirmed (or refuted as the case may be) as being true (or false) descriptions of reality. The turning point for this view of science came about with the publication of Norwood Hanson's Patterns of Discovery[22] in 1958. There Hanson points out that all observation is "theory-laden," and thus conditioned, or even impure. This notion of theory ladenness of observation certainly sounds the death knell for neo-positivism and the received view of science that require observation to be theory free; but, as we shall see, it needn't cause us to abandon a notion of objectivity.

Then with the publication of Thomas Kuhn's Structure of Scientific Revolutions[23] in 1962 we get not only the claim that science is revolutionary rather than progressive, but the assertion that there is no neutral non-arbitrary algorithm for theory assessment and theory choice. Kuhn also emphasizes the social dimension of the scientific enterprise, thus opening it

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[22] N. R. Hanson, Patterns of Discovery (Cambridge: Cambridge University Press, 1958).

[23] Thomas Kuhn, The Structure of Scientific Revolutions (Chicago: University of Chicago Press, 1962).

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up to sociological and psychological critique, especially as he describes his theoretical paradigm shifts in the language of gestalt theory. Even preceding Kuhn there is the seminal work of Michael Polanyi and his notion of "tacit knowledge" as discussed in his 1958 work Personal Knowledge.[24] Thus with the emphasis on the ineliminability of the theoretical and the emphasis on the social aspect of scientific inquiry one sees understanding creeping back into the scientific enterprise. So while as a result of the direction of more recent philosophy of science it would seem that philosophers of science would at least have to acknowledge the hermeneutic position and allow understanding into the natural sciences, nevertheless the problem of demarcation remains unresolved.

Even Gadamer, for all of his insistence on the inescapability and universality of the hermeneutic situation, remains relatively silent when it comes to what extent our "horizons" or "prejudices" influence our natural scientific theory. Although he is a bit more forthcoming in his more recent work, his hermeneutic treatment of the natural sciences seems to come in fits and starts.

I would like to suggest that these inabilities to address adequately the problem of demarcation rest on a fundamental confusion regarding what it means to hold a universal hermeneutic. The problem is typified by considering the

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[24] Michael Polanyi, Personal Knowledge (Chicago: University of Chicago Press, 1958).

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extreme positions, represented by someone like Taylor and Dreyfus (and of course Dilthey) on the one hand, and Feyerabend and Rorty on the other. On the first, more conservative side, nature is seen as being without intrinsic meaning. As Taylor is wont to remind us, rock formations and snow crystals have no meaning, despite their having coherent patterns.[25] When we explain such physical objects or events we are not searching for any hidden meanings behind them; we merely explain what is observed or experienced in an attempt to organize the data. On this view, it is only the historical "human sciences" that can be considered properly hermeneutic. Thus, it is only with regard these disciplines that we seek understanding inasmuch as it is only human actions or products/artifacts that are considered to have any sort of meaning. There certainly are vestiges of a positivist notion of natural science on this view.

On the other hand, the liberal extreme disallows any objective account of natural science that is different in kind from a description of the world found in any other discipline--whether it be literature in the case of Rorty or astrology and witchcraft in the case of Feyerabend. Scientific theories are one way of picturing the world--not terribly different from a sonnet.

My position falls somewhere in the middle and requires a

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[25] See especially, Charles Taylor, "Interpretation and the Sciences of Man" Review of Metaphysics 25 (1971) 3-34, 45-51.

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redefining of what is meant by a "universal hermeneutic." Accepting the hermeneutic situation as conceived by Gadamer as my starting point, I maintain that such events or happenings of understanding described in Truth and Method (as well as other places), are equally pertinent to the physical sciences.

Accepting understanding as primordial and constitutive of our human condition, inasmuch as the natural sciences involve human knowers, they too are hermeneutic. Understanding is an ontological description of our situation in the world and hence inescapable. That is to say, it is not ours to choose which disciplines are properly hermeneutic. As David E. Linge states in his introduction to Gadamer's Philosophical Hermeneutics, "the task of philosophical hermeneutics, therefore, is ontological rather than methodological. It seeks to throw light on the fundamental conditions that underlie the phenomenon of understanding in all its modes, scientific and nonscientific alike, and that constitute understanding as an event over which the interpreting subject does not ultimately preside"[26] In every situation that involves a human knower, understanding (and therefore interpretation and meaning) plays a crucial role. Given this essential nature of understanding, the old (positivist) picture of science denies a fundamental aspect of what it means to be a human knower. In that respect we shall see how

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[26] Hans-Georg Gadamer, Philosophical Hermeneutics, translated and edited by David E. Linge (Berkeley: University of California Press, 1976), editor's Introduction, p. xi.

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Bohr's concerns with language and communication, and his more unorthodox notions of truth and objectivity can be seen to reflect the position of an ontological hermeneutics that centers around understanding.

On this position, any attempt to draw a distinction among the sciences along the lines of the role (or lack thereof) of the understanding falls apart. But that does not mean that the issue of demarcation becomes moot, as someone like Rorty would argue. It just means that we need some other mode of comparison, one that acknowledges the social dimension of the scientific enterprise, the importance of the role of language for the scientist in theory formation, and the emphasis on the hermeneutic notion of dialogue at work in any attempt to understand a scientific experiment or tradition. (All these will be shown to be manifest in Bohr's philosophical concerns).

If we accept what Gadamer has claimed about understanding, it becomes <u>part</u> of the explanatory process; what happens "<u>beyond</u> our making and doing," or as Gadamer himself has said, "behind our backs." Thus hermeneutics becomes vital to the explanatory sciences or <u>Naturwissenschaften</u> as well.

Nevertheless, as a result of the emphasis on the role of history and understanding in the natural sciences, what one faces is the accusation of relativism. Hermeneutics brings along with it a historicity and contextualism that causes

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objectivists and metaphysical realists to squirm. And yet, as is the case with both hermeneutic theory and Bohr's interpretation of quantum theory, neither will leave us in a mire of relativism. In that respect, both philosophical hermeneutics and quantum theory are indicative of the claim that we have moved beyond the exclusionary either/or of objectivism and relativism. Both will allow us to maintain a notion of "objectivity" in the face of an ineliminable "subject." (We will return to this in the chapters below).

Indeed, Gadamer himself sees the anti-relativist arguments as being trivial and inconsequential, as he states in Truth and Method, "However clearly one demonstrates the inner contradictions of all relativist views, it is as Heidegger has said: all these victorious arguments have something about them that suggests that they are attempting to bowl one over. (Being and Time 272). However cogent they may seem, they still miss the point. In making use of them one is proved right, and yet they do not express any superior insight of any value. That the thesis of skepticism or relativism refutes itself to the extent that it claims to be true is an irrefutable argument. But what does it achieve? The reflective argument that proves successful here falls back on the arguer, in that it renders the truthfulness of all reflection suspect. It is not the reality of skepticism or of truth dissolving relativism, but the claim to truth of all

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formal arguments that is affected."[27] It will be interesting to consider this statement in light of Bohr's proposal of what he calls "deep truths" where the opposite may also contain a kernel of truth.

What comments like these are indicative of is an attempt to overcome the exlusionary choice between realism and relativism and get "beyond" them. That is not to say we can merely sweep them aside, but rather to suggest that the lines between the choices are no longer so clearly defined. We shall see how Bohr's thought reflects the same attempt to get beyond these more traditional dichotomies, as he attempts to define both truth and objectivity in terms of contextualism and with reference to a subject.

Finally, as John Honner claims in his work entitled The Description of Nature: Niels Bohr and the Philosophy of Quantum Physics, "Though the quantum postulate has not altered metaphysics, its discovery has drawn physics and metaphysics into a closer and possibly fruitful proximity."[28] So while the line of demarcation between the human and the natural sciences is not eliminated, quantum theory remains an instance where the two sides are drawn, if not closer, then at least into dialogue.

We now turn to a brief history of quantum physics in

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[27] Truth and Method, p. 308-9.

[28] Honner, John, The Description of Nature: Niels Bohr and the Philosophy of Quantum Physics (New York: Oxford University Press, 1987).

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order to lay the groundwork for the more philosophical interpretation by Bohr that is to come.

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III. Quantum Theory and Niels Bohr

(a) A brief history of Quantum Theory

Quantum physics seems to have its conceptual precursor in the seventeenth century conflict regarding the nature of light. The question in dispute was as follows: Is light fundamentally a wave-like phenomenon, as Grimaldi had proposed, his undulatory theory finding development through the work of Huygens and Hooke, or is light of a corpuscular nature, as Newton maintained, and later Biot, and Laplace would argue. As we know, both theories were, (up until the nineteenth century) able to account for phenomena like reflection and refraction, but with differing conclusions. And since Huygens' wave theory of light was able to duplicate all of the optical phenomena that were known in the seventeenth century as adequately as Newton's theory, the dilemma remained unresolved. The true source of the problem lies in the fact that the choice between a wave and a particle is one that is mutually exclusive. By their very natures, one cannot describe the same thing as both a wave, which is divisible by nature, not localizable by coordinates, infinite in extension, and able to occupy the same space with another wave, and a particle, which is indivisible (ideally speaking), identifiable by sharp coordinates, finite in extension, and by definition occupies exclusive space. Thus it became

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unthinkable that any object or event could be describable in both these ways at once. Remarking on the difficulty Norwood Hanson points out that "'Unthinkable' here means not simply 'unimaginable' but also 'notationally impossible.' For in the only languages then available for describing particle and wave dynamics, such a joint description of phenomena would have constituted a virtual contradiction."[29]

The true nature of light then remained controversial for many generations. It was not until experimentation like that of Young's Double Slit Experiment showed the insufficiency of Newton's theory to account for the diffraction of light, that some headway was made. As we know, the controversy was temporarily put to rest in the nineteenth century by experimentation that led to the discovery that light is nothing more than the propagation of an electromagnetic force between coupled charged bodies. Thus, science reached a state of contentment regarding the "true" nature of light. That is, of course, until the experimentation by Max Planck around the turn of the century on black-body radiation. As a result of Planck's experimentation, wave-particle dualism was once again thrust into the spotlight and made the center of a controversy that would lead to a complete revision of how physics views the world. As Gerald Holton states, "the renovation of quantum physics...marked a turning point in the road from

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[29] Norwood Hanson, "Philosophical Implications of Quantum Mechanics" in Encyclopedia of Philosophy vol. 7 (New York: Macmillan, Inc, 1967) p. 42.

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which our view of the intellectual landscape, in science and in other fields, will forever be qualitatively different from that of other periods."[30] What follows is a brief description of some of the paradoxes encountered at these early stages of experimentation and a consideration of how they would bring about such a conceptual revolution and contribute to the formulation of the Copenhagen interpretation of quantum physics.

In his brief chapter on the history of quantum theory, Werner Heisenberg begins with the following account:

> The origin of quantum theory is connected with a well-known phenomenon, which did not belong to the central parts of atomic physics. Any piece of matter when it is heated starts to glow, gets red hot and white hot at higher temperatures. The color does not depend much on the surface of the material, and for a black body it depends solely on the temperature. Therefore, the radiation emitted by such a black body at high temperatures is a suitable object for physical research; it is a simple phenomenon that should find a simple explanation in terms of the known laws for radiation and heat...(But) the application of the known laws did not lead to sensible results.[31]

It was in trying to account for these anomalous results that the quantum nature of reality would first be revealed. In 1895, Max Planck joined the research on these so-called black bodies, turning attention from radiation to the radiating atom (the oscillator). What Planck soon concluded was that in

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[30] Gerald Holton, "The Roots of Complementarity" in Thematic Origins of Scientific Thought (Cambridge: Harvard University Press, 1973), p. 115.

[31] Werner Heisenberg, Physics and Beyond (London: G. Allen & Unwin, 1971), p. 30.

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order to account for the inexplicable experimental results on such black bodies, one must treat the radiated energy not as continuous (as classical physics demanded) but rather as discrete bundles of energy. This notion of a "bundle of energy" introduces into nature an element of discontinuity that is quite foreign to classical physics. To be sure, the results of such an introduction would be astounding for physicists and philosophers alike. As Heisenberg, among others, has pointed out, this discovery on the part of Planck was a result that was "so different from anything known in classical physics that he certainly must have refused to believe it in the beginning."[32] In fact, Planck himself is quite candid about his trepidation regarding making public his discovery[33] and he resisted doing so for as long as possible[34]. Nonetheless, Planck did publish his findings in December 1900 in the form of his epoch making equation, ($E = hv$), where the constant of proportionality "h", between the energy of a mode of electromagnetic radiation, E, and its frequency "v" is a universal constant. He described the

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[32] Ibid., p. 31.

[33] See especially, Planck, The Philosophy of Physics (New York: Norton Publishing Co, 1936); Pais: Niels Bohr's Times (New York: Oxford University Press, 1991); and Heisenberg states in Physics and Philosophy (London: G. Allen & Unwin, 1971), p. 31, "Planck, who was conservative in his whole outlook, did not like this consequence at all, but he published his quantum hypothesis in December of 1900."

[34] There are many accounts given by his son regarding Planck's reluctance to make public his findings, fearing what the consequences would be for our understanding of nature.

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oscillator as containing discrete packets of energy, or Energieelement which could be related to the frequency of vibration of the oscillating particles emanating the radiated energy by virtue of this constant, 'h'--denoting an extremely small number[35]. In the following year, Planck introduced the term Elementariquanta to be used in place of Energieelement, and as John Honner notes, "the era of quantum physics thus received its emblem. Planck himself called "h" the 'quantum of action,' since it had the physical dimensions of action, namely, work multiplied by time. More commonly, however, it became known as 'Planck's constant,' though Bohr himself continued to refer to it as the quantum of action."[36]

As mentioned above it is well documented that Planck realized the magnitude of his discovery, as he often compared the discovery of the quantum of action to the discoveries of Newton, aware that his findings would revolutionize the way we think of Nature and the ultimate constituents of reality. And thanks to the work of Niels Bohr, Planck's suspicions came true.

What is so startling, even to a lay person, about the discovery of the quantum of action is that since the frequencies lie in a discrete set of values, (Planck's quantization condition), "E = hv" implies that so must the energies of these different modes of electromagnetic radiation

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[35] The value of Planck's constant is 6.624×10^{-27}.

[36] John Honner, The Description of Nature, p. 30.

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lie in a discrete spectrum. Thus, one must conclude, certain values of energy in the radiation field do not exist. If E(a) and E(b) are "neighboring" energy values for the radiation, there is no other energy between them for this radiation.

Planck's conclusion was that electromagnetic radiation may be considered an ensemble of discrete quanta (of photons), and between any two energy values, there is a genuine gap where there is no energy value available.[37] Naturally questions would arise regarding the source of this gap. Is it a deficiency of the theory, a limitation imposed as a result of inadequate instruments, or perhaps a limitation of our knowledge stemming from our inadequacies to know certain things about nature?--or further yet, (as Bohr will insist), perhaps the gap is a result of Nature herself. These philosophical issues will form the core of the discussions regarding quantum theory and will all be taken up and addressed as the story unfolds. Again, what is most unpalatable for classical theorists is the introduction of this element of discontinuity into the behavior of nature. Along with this most un-classical notion of discontinuity, comes a limitation on our knowledge. A more deterministic theory would demand to know the energy values between E(a) and E(b). And yet, we are being told that such determination is

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[37] See especially Mendel Sachs: Einstein versus Bohr: The Continuing Controversies in Physics (LaSalle: Open Court Books, 1988) for a nice summary of the formulation of Planck's equation and the initial difficulties it posed for both classical theory and common sense.

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not possible precisely because such values do not exist. This marks the first erosion in our familiar intellectual landscape.

As Bohr himself would soon remark, the eventual applications of quantum theory to atomic problems was

> ...destined to reveal a hitherto unnoticed limitation that found its expression in Planck's discovery of the so-called quantum of action, which imposes upon individual atomic processes an element of discontinuity quite foreign to the fundamental principles of classical physics, according to which all actions may vary in a continuous manner.[38]

And yet, as Bohr would likewise point out, "the quantum of action has become increasingly indispensable in the ordering of our experimental knowledge of the properties of atoms."[39] Will it turn out that we will have to abandon the classical concept of continuity? And yet all our experiences at the macro-level confirm continuity of experience and a continuum. Despite these obvious confirming instances in favor of continuity, the fact remains that, as Bohr had reminded us, the quantum of action was proving indispensable in the ordering of our experiences. It is precisely such "ordering of our experiences" that is part and parcel of the scientific enterprise. In fact, in 1929, Bohr defined the very task of science as being both "to extend the range of our experience

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[38] Niels Bohr, The Philosophical Writing of Niels Bohr, Vol. I: Atomic Theory and the Description of Nature (Woodbridge CT: Ox Bow Press, 1987), p. 4. Hereafter Bohr, Vol. I.

[39] Ibid.

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and to reduce it to order."[40] (We will return to this definition below.) Thus we are given the first glimpse of the conceptual contradictions inherent in the quantum description. I will maintain that what Bohr decides to do with those contradictions is what makes his philosophy hermeneutic. But before we begin an exposition of his philosophy, we return to our brief history of the development of quantum theory.

Another area where the quantum of action proved indispensable was in the work of that scientist who would prove to be the most antithetical to the quantum description: none other than Albert Einstein himself, the conceptual nemesis par excellence of quantum theory. In 1905, at that time relatively unknown in the scientific community, Einstein "transplanted the notion of the quantum from the nursery of thermodynamics into the complex world of atomic physics."[41] There were two problems where Einstein saw possible use for the "new ideas" of the quantum. The first was another experiment that had produced curious results, the so-called "photo-electric effect," which involved the emission of electrons from metals under the influence of light. Experiments had shown that the energy of the emitted electrons did not depend on the intensity of light, but only on its color or frequency. This could not be understood on the basis of the traditional theory of radiation. As John Honner

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[40] Niels Bohr, Vol. I, Introductory Survey p. 1.

[41] John Honner, The Description of Nature, p. 30.

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describes it, the traditional theory had predicted the following:

> ...the velocity of the dislodged electrons should increase in proportion to an increase in the intensity of the incident radiation. In fact, however, the velocities remained constant and it was the number of electrons being dislodged that was observed to increase. Moreover, one would expect from classical theory that as the energy of incident radiation was reduced, then the dislodging of electrons would simultaneously taper off. Curiously, however, below a certain threshold of energy, no matter how long one applied radiation, no electrons were dislodged at all. There was a startlingly abrupt cut-off point.[42]

Einstein proposed explaining the observations by the application of Planck's constant to the travelling of light through space. In other words, if we considered the incident radiation as small packets of energy, with the quantity of the energy being directly proportional to the frequency of the radiation, then the energy of one light quantum should, in agreement with Planck's assumptions, be equal to the frequency of the light multiplied by Planck's constant. What this did, however, is attribute to light properties of particles, returning to a theory long since thought to have been dismissed--namely, the particulate theory of light. How was one to treat the newly resuscitated wave-particle dilemma regarding the nature of light?

The second problem that Einstein solved with the use of Planck's constant and the notion of the quantum was the specific heat of solid bodies. Heisenberg aptly describes the

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[42] Ibid.

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course of events as follows:

> The traditional (classical) theory led to values for the specific heat which fitted the observations at higher temperatures but disagreed with them at low ones. Again, Einstein was able to show that one could understand this behavior by applying the quantum hypothesis to the elastic vibrations of the atoms in the solid body.[43]

Thus Einstein's work revealed the presence of Planck's quantum of action in several phenomena that had nothing to do (directly) with heat radiation. But, perhaps more importantly, as Heisenberg further points out,

> They revealed at the same time the deeply revolutionary character of the new hypothesis, since the first of them led to a description of light completely different from the traditional wave picture. Light could either be interpreted as consisting of electromagnetic waves, according to Maxwell's theory, or as consisting of light quanta, energy packets traveling through space with high velocity.[44]

The question soon arises, as Heisenberg and Bohr will both point out, could light be both? Therein lies the dilemma. As was stated above, admitting that light exhibited characteristics of both a wave and a particle leads to seemingly irreconcilable contradictions that fly in the face of classical theory not only in physics, but in philosophy as well. If two descriptions are mutually exclusive as the wave and particle descriptions are, they cannot both be the case. And no self-respecting realist would allow both descriptions to co-exist. So it would seem that wave-particle dualism, if

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[43] Werner Heisenberg, Physics and Philosophy, p. 32.

[44] Ibid, p. 32.

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irreconcilable, decides matters in favor of the anti-realist[45]. And yet, as we will see, the philosophical system of Niels Bohr in accepting wave-particle dualism and trying to formulate a conceptual framework to accommodate both pictures is in no way incompatible with realism, albeit a different sort of realism. Nevertheless, the development of the theory continues:

Aware of the evidence in favor of Maxwell's wave-theory (its ability to explain the phenomena of diffraction and interference) over any theory that described light as exhibiting particle-like characteristics (and clouded by many distorting conceptual prejudices that will be make explicit in the chapters to follow), Einstein chose to interpret his results in a purely heuristic fashion, with the belief that the seeming contradiction would eventually work its way out.[46] Nonetheless, Einstein had (re)opened the door to wave-particle dualism in such a way that physics would never be the same.

Perhaps the most influential use of the new quantum of action and its concomitant notion of discontinuity was its application to the structure of the atom itself. In 1911, Ernest Rutherford discovered the structure of the atom to be the following: the atom was made up of a relatively heavy

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[45] See Jarrett Leplin's, Scientific Realism, on this.

[46] Again, more adequate treatment of the Einstein-Bohr debate will be given below.

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positive nucleus around which the small negatively charged electrons spun. The nucleus of the atom, despite its small size, contains nearly the total mass of the atom, while the electrons circle the nucleus in a way similar to the way the planets circle around the sun. What this picture of the atom could not explain, however, was the atom's relative stability. In other words, after a collision with another atom, (in the form of chemical binding) an atom will go back to its original configuration. The analogy of basing the description of the orbit of the electron on the orbits of the planets around the sun soon loses its strength considering that "no planetary system following the laws of Newton's mechanics would ever go back to its original configuration after a collision with another such system."[47] Nor would any planet knocked out of its orbit resume its place in the celestial system. Nonetheless, this is precisely what took place when electrons were "knocked" out of their orbits. It was in addressing these dilemmas that Bohr formulated what is known as the "old" quantum theory of 1913. Working alongside Rutherford at the latter's laboratory in Manchester, Bohr found that classical theory was of no help. So he turned to the quantum of action for assistance. As Honner describes it,

> Drawing on the work of Planck and Einstein, Bohr explored the hypothesis that the kinetic energy of rotating electrons was related by some constant to the frequency of rotation. By June 1912 the Bohr atom was beginning to take shape, and Niels wrote to his brother Harald that he

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[47] Werner Heisenberg, Physics and Philosophy, p. 34.

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had discovered 'perhaps a little bit of reality.'[48]

What Bohr did was apply Planck's quantum hypothesis to the orbit of an electron. As Bohr himself phrased it in his monumentous paper "On the Constitution of Atoms and Molecules,"

> In any molecular system consisting of positive nuclei and electrons in which the nuclei are at rest relative to each other and the electrons move in circular orbits, the angular momentum of every electron round the centre of its orbit will in the permanent state of the system be equal to $h/2\pi$, where h is Planck's constant."[49]

Bohr maintained that the electron would not lose energy by radiation while in orbit, but would do so merely in transition from one orbit to the other. Thus he was able to "save" the atom from gradually collapsing with the emission of a spectrum line of continuously changing frequency. What Bohr showed was that if the atom can change its energy only by discrete energy quanta, this must mean that the atom can exist only in discrete stationary states, the normal state of the atom being the lowest, or ground state, the innermost orbit. This explains why after any kind of interaction the atom will finally always fall back to its normal state; Hence the explanation of the stability of the atom utilizing the notion of discontinuity heralded by Planck's quantum of action. Analogous to the discontinuity of the energy values in the photo-electric effect, an electron can move from orbit to

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[48] John Honner, The Description of Nature, p. 33.

[49] Bohr, "On the Constitution of Atoms and Molecules" cited in John Honner The Description of Nature, p. 34.

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orbit, but it cannot occupy any place between these orbits. The mysterious term 'quantum jump' thus referred to a sudden transition from one level to another, imposing another limitation on our knowledge inasmuch as the quantum jumps are discrete, with no values in between. But again, as Bohr will emphasize, this is not a limitation due to our instrumentation, or to our limited nature as human knowers, but rather a limitation imposed by Nature herself. Therein will lie the source of Bohr's realism.

In addition to explaining the stability of the atom, Bohr's application of quantum theory to the atomic model gave a theoretical interpretation to well-defined spectral lines resulting from the movement of electrons between stationary states when atoms were excited by means of electric charge or heat. As a result, Bohr's new field of application for the quantum theory proved monumentous for scientists, opening up a new line of research.

Perhaps most importantly, as Heisenberg points out, "it was from this time on that the physicists learned to ask the right questions; and asking the right question is frequently more than halfway to the solution of the problem."[50] And the precise issue that would be once again at the center of these questions would be wave-particle dualism. What should we make of this persistent dilemma? Is it solvable? If not what kind of more far-reaching effects will it have on our understanding

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[50] Werner Heisenberg, Physics and Philosophy, p. 35.

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of what we can know about nature--or more importantly for Bohr, what we can say about nature?

One of the most curious of the early attempts to reconcile the wave-particle dualism was by none other than Bohr himself. Early on in the development of quantum theory Bohr proposed the "Correspondence Principle," which, (in a very crude description) asserts that what cannot be achieved with classical theory is subjected to quantum considerations, and vice versa. As a result, classical physics and quantum physics produce equivalent results for high quantum numbers (at the macroscopic scale). Nonetheless the seeming success of the correspondence principle was short-lived. As Gerald Holton notes, "the correspondence principle of 1918 was a moderately successful half-way house toward the reconciliation between classical and quantum mechanics."[51] But correspondence was soon abandoned by Bohr as it proved to be more and more unsuccessful. Nonetheless, as Bohr would insist, it was precisely the correspondence principle that allowed Heisenberg to formulate his indeterminacy paper and uncertainty principle.[52]

As a result of the failure of the correspondence principle, Bohr sought out resolution of wave-particle dualism elsewhere. He was at the time extremely reluctant to abandon the wave-theory of light, for it offered a realistic account

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[51] Gerald Holton, "The Roots of Complementarity," p. 130.

[52] This will be discussed below.

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of the nature of radiation. It is no surprise, then that Bohr rejected Einstein's notion of light quanta, as he said of it "the hypothesis under discussion can in no wise be regarded as a satisfactory solution...The hypothesis of light-quanta, therefore, is not suitable for giving a picture of the processes in which the whole of the phenomena can be arranged, which are considered in the application of the quantum theory."[53] What might seem at first to be an agreement with Einstein regarding the heuristic nature of the theory, was in actuality a realization en route to the formulation of "complementarity": the suspicion that either the light picture or the wave picture on its own was inadequate. In the meantime in 1922 experiments by A. H. Compton seemed to weigh the evidence heavily in favor of the particle character of light, making resolution of the dilemma even more urgent.

Another of Bohr's early attempts to solve the wave-particle dualism came in the form of the Bohr-Kramers-Slater paper titled "The Quantum Theory of Radiation." Written in 1924, it tried to solve the dilemma by the postulation of a "probability wave." But shortly after its publication in 1924, further experimentation by Compton, as well as Walter Bothe and Hans Geiger gave disconfirming results to both the correspondence principle and the Bohr-Kramers-Slater paper. As Holton declares, "The correspondence principle, it appeared

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[53] Niels Bohr, "On the Application of the Quantum Theory to Atomic Structure," cited in John Honner, The Description of Nature, p. 37.

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now clearly, had been a useful patch over the fissure, but it was not a profound solution."[54] Nonetheless, these early attempts by Bohr to resolve the wave-particle dualism did prove useful for his eventual formulation of complementarity. Remarking on the usefulness of the abandoned paper, Heisenberg declares that it "introduced the hypothesis that the waves are of the nature of probability waves: that they represent not a reality in the classical sense, but rather the 'possibility' of such a reality."[55] Heisenberg emphasizes the fact that while completely off the mark in solving the wave-particle dualism, the Bohr-Kramers-Slater paper nonetheless was instrumental in leading to the "new" quantum theory in the form of the Copenhagen interpretation in that it introduced into theoretical physics the notion of 'probability,' something that Max Born would find indispensable in his probabilistic interpretation of quantum theory. In fact Born's interpretation of wave mechanics would prove to be the most influential precursor for the Copenhagen School as it would give the interpretation that would eventually be adopted by the consensus of the physics community. Born assumed that accompanying each elementary particle of matter (as well as the quanta of radiation) there must be a 'cloud of

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[54] Gerald Holton, "Roots of Complementarity," p. 131.

[55] Werner Heisenberg, "The Development of the Interpretation of Quantum Theory" in Wolfgang Pauli, ed., Niels Bohr and the Development of Physics, cited in John Honner, The Description of Nature, p. 38.

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probability.' This entails the chance of measuring particular physical properties of these elements of matter or radiation at any particular time and place.[56] This emphasis on probability was, according to Heisenberg, a reintroduction of Aristotelian potentia into the picture. As Heisenberg described it, "it introduced something standing in the middle between the idea of an event and the actual event, a strange kind of physical reality just in the middle between possibility and reality."[57] It is precisely this introduction of the notion of 'probability' that, as we shall see below, will prove most problematic for Einstein. As he often noted, if it were the case that in the end the electron were left to decide which direction it would go, then Einstein would abandon physics and be more content as a cobbler.

The indispensability of the quantum of action by no means ended there. In 1924, the idea of wave-particle dualism was extended to the nature of elementary inertial matter by Louis de Broglie. Mendel Sachs describes the theory as follows:

> In his doctoral thesis Louis de Broglie hypothesized that just as the energy and wavelength of a quantum of radiation are reciprocally related, so the particle and wave aspects of inertial matter, such as electrons, must be reciprocally related. He then postulated that the 'particle' property of an electron, say its momentum p, is related to its wave property, its wavelength l, as follows:
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> $$p = h/l$$

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[56] See Mendel Sachs, Einstein versus Bohr, p. 116 ff.

[57] Werner Heisenberg, Physics and Philosophy, p. 41.

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where h is Planck's constant.[58]

De Broglie put wave-particle dualism once again into the forefront in his theory of matter-waves, which would pave the way for the development of Schrödinger's wave-mechanics, and the attempt to resolve the dilemma in the favor of a wave theory. What we will see, however, is that attempts like that of Schrödinger's (including Heisenberg's wave-mechanics) were merely a way of hiding the paradoxes in the formalism of a new mathematical scheme, and are by no means satisfactory.[59]

Despite the difficulties it introduced to the description of nature, Planck's discovery of the quantum of action proved more and more invaluable for explaining physical phenomena in all areas of experimentation. (One could only imagine that at that point it was thought possible for Planck's constant to be instrumental in finding a cure for the common cold!) As Bohr himself notes,

> In the history of science there are few events which, in the brief span of a generation, have had such extraordinary consequences as Planck's discovery of the elementary quantum of action. Not only does this discovery, to an ever increasing degree, form the background for the ordering of our experience concerning atomic phenomena, the knowledge of which has been so amazingly extended in the last thirty years, but, at the same time, it has brought about a complete revision of the foundations underlying our description of natural

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[58] Mendel Sachs, Einstein versus Bohr, p. 85.

[59] Even Heisenberg himself will remark on the insufficiency of the new formalism and denounce his own early work as youthful zeal for a mathematical solution. See especially Physics and Beyond, and Across the Frontiers (Woodbridge , CT: Ox Bow Press, 1990).

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phenomena.[60]

It is precisely this call for a revision of conceptual foundations, or "framework" as he will call it, that preoccupied the philosophical writings of Niels Bohr. His response to such notions as limitations on knowledge, discontinuity in nature, wave-particle duality, etc. in the form of the Copenhagen interpretation of quantum physics form the backbone of a intricate philosophical theory which is at base an epistemology whose utmost concern is communicating to others what one can know. What Bohr will do is rather than explain away the difficulties by means of some dependence on instrumentalism or some heuristic notion of scientific theory, he will embrace the very paradoxes and dilemmas that quantum theory provides. In fact what many scientists see as purely problematic and troublesome in the theory Bohr will see as fortuitous for both the physicists and the philosophers alike. It is fortuitous in the sense that it will force us to take note of our general situation as human knowers in the world, a situation rife with problems that might otherwise go unnoticed. In fact, according to Bohr, quantum physics forces us to be critical where we might otherwise not be. In that sense we are grateful to the problems quantum physics opens up to us. In fact, Bohr will come to see natural science as unique in its ability to extend our range of experience unlike

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[60] Niels Bohr, "The Quantum of Action and the Description of Nature" in Bohr, Vol. I, p. 92.

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any other discipline. And what that extending of experience offers us is not so much predictive power and control, but rather, (or more importantly for Bohr), the opportunity to examine our situation as human knowers who must communicate to others what we have experienced. This will become much clearer as we examine his philosophical writings.

The final step toward the Copenhagen interpretation came with advances on the part of Heisenberg himself. First, quite unaware of Schrödinger's success with wave mechanics, Heisenberg developed a formalism at the same time that was equally successful. This was the matrix mechanics. Basically matrix mechanics was a set of rules for combining groups of numbers or matrices, whereby results were obtained that turned out to be equal in success to Schrödinger's wave mechanics. In fact the two formalisms were shown to be mathematically equivalent, much to the chagrin of both scientists involved. Nonetheless, as was mentioned above, Heisenberg himself will admit that even his own matrix mechanics was guilty of merely hiding the paradoxes in the formalism and leaves one with a most unsatisfactory feeling of not having understood the theory.

Secondly, and more importantly, the final ingredient in the formulation of the Copenhagen interpretation came out of Heisenberg's indeterminacy principle and the "measurement problem." Given the nature of atomic reality, any attempt to

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observe a particle somehow "disturbs"[61] the particle itself. This imposes another limitation on our knowledge as it would seem that we can never have an accurate reading of any measurement of a particle. Heisenberg would make more explicit this limitation in the form of an uncertainty regarding certain attributes of the particle. As Bohr himself describes it,

> This phase of the development was initiated in 1927 by Heisenberg, who pointed out that the knowledge obtainable of the state of an atomic system will always involve a peculiar "indeterminacy." Thus, any measurement of the position of an electron by means of some device, like a microscope, making use of high-frequency radiation will, according to the fundamental relations be connected with a momentum exchange between the electron and the measuring agency, which is the greater the more accurate a position measurement is attempted.[62]

There are a number of "canonically conjugate" variables such as position/momentum; time/energy, etc., such that the more accurately one determines the first, the less accurately one can know the second. For example, if one can determine the position of an electron (NB: given the measurement problem this initial determination will never be accurate in the classical understanding of the word), then the momentum of the same electron cannot be given a determinate value. And the higher the precision in knowing the position, the lower the

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[61] Bohr's eventual abandonment of the term "disturb" will be discussed at length below.

[62] Bohr: "Discussion with Einstein on Epistemological Problems in Atomic Physics" (1949) in The Philosophical Writings of Niels Bohr, Vol II, "Essays 1932-1957 on Atomic Physics and Human Knowledge," p. 38-9. Hereafter, Bohr, Vol. II.

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accuracy of knowing its momentum. The uncertainty relations are limitations on our knowledge of the electron, or whatever particle is in question, at the sub-atomic level. These are uncertainties that in principle cannot be eliminated, and thus are part of the fabric of reality, not a limitation in our measuring devices.

After initial resistance, Bohr came to see Heisenberg's uncertainty relations as an expression and confirmation of his concept of "complementarity." As he would note,

> (the new indeterminacy relations) may be regarded as a simple symbolical expression for the complementary nature of the space-time description and the claims of causality.[63]

Niels Bohr's reactions to the situation in physics that I have briefly described took the form of what is referred to as the "Como Paper," a paper delivered in September of 1927 at the occasion of Volta Centenary Congress in Como, Italy, and then given again at the Solvay Conference in Brussels two months later. In the paper, Bohr introduces his notion of complementarity for the first time and tries to make explicit that the problems encountered in quantum theory center around the problem of language. In fact, language remains at the heart of the Copenhagen interpretation as conceived by Bohr, and, as we shall see, it is his understanding of language that supports our claim that his philosophy is essentially hermeneutic. The emphasis Bohr places on language, especially

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[63] Niels Bohr, "The Quantum Postulate and the Recent Development of Atomic Energy," in Bohr, Vol. I, p. 53.

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as it is used in communication will open the door to general hermeneutic concerns that I will maintain were at the center of Bohr's philosophy. The importance of language in the Copenhagen interpretation can be shown from the following description by Heisenberg. He states that,

> The Copenhagen interpretation of quantum theory starts from a paradox. Any experiment in physics, whether it refers to the phenomena of daily life or to atomic events, is to be described in the terms of classical physics. The concepts of classical physics form the language by which we describe the arrangement of our experiments and state the results. We cannot and should not replace these concepts by any others. Still, the application of these concepts is limited by the relations of uncertainty. We must keep in mind this limited range of applicability of the classical concepts while using them, but we cannot and should not try to improve them."[64]

This is a clear statement of the claim that the problem lies in the fact that the only language we have to describe our experiences, the classical language of every day experience, (or, what Husserl referred to as language of the "life-world"), cannot accommodate our experiences at the atomic level. Given the present scope of our concepts, they cannot be used to describe what is encountered in experiences at the quantum level. Thus the limitation lies on the part of language. And yet, this language, classical language, (derived from an interplay with the classical world) is the only language we have; it is the language of everyday experience. We should not try to formulate any other language, since ultimately we need to communicate our

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[64] Werner Heisenberg, Physics and Philosophy, p. 44.

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experiences to others. In fact, as we shall see below, Bohr's very own definition of "objectivity" as "unambiguous communication" validates this emphasis on language and heralds in a concern about the social dimensions of science.

Bohr's response to the limitation we encounter on the part of language will be his notion of complementarity, and will be given full treatment below. For now suffice it to say that complementarity is seen by Bohr as that device that will allow our language to be effective where it might otherwise not be. But in order for complementarity to fulfill its function and be an effective remedy for the breakdown of language, as it is often called, Bohr will require that we rethink some of our philosophical and conceptual assumptions. This will all be treated below under the heading of "Complementarity."

So, as we begin the discussion of Bohr's philosophical writings, we sum up the profound differences between classical description and quantum description of reality as follows:[65]

(1) In classical physics, the "state of the system" can (at least in principle) be observed, described, defined with arbitrarily small interference of the behavior of the object on the part of the observer, and with arbitrarily small uncertainty.

In quantum physics, the "state of the system" cannot be observed without significant influence upon the state. There

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[65] Extracted from Holton, "Roots of Complementarity."

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is some sort of energy exchange according to the quantum postulate, which implies a fundamental discontinuity in possible results.

(This is a result of the measurement problem described above)

(2) A classical system can be considered closed although it is being observed, since the flow of energy into and out of the system during an observation is negligible compared to the energy changes in the system during interaction of the parts of the system. In a quantum system, however, one cannot neglect the interaction between the "system under observation" and the "agency" --or interaction between the object and the subject. The standard example is Heisenberg's gamma-ray microscope, in which the progress of an electron is "watched" by scattering gamma rays from it, with the result that the electron itself is deflected from its original path.

(3) In classical physics we have conventional causality chains and ordinary space-time coordination, and both can exist at the same time. In quantum systems, there are no conventional causality chains: if left to itself, a system such as an atom or its radioactive nucleus undergoes changes (such as emission of a photon from the atom or a particle from the nucleus) in an intrinsically probabilistic manner.

(4) Finally, the wave-particle paradox. As Bohr himself describes it,

> [The] propagation [of light] in space and time is adequately expressed by the electromagnetic theory. ...Nevertheless, the conservation of energy and momentum during the interaction between radiation and matter, as

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> evident in the photoelectric and Compton effects, finds its adequate expression in the light quantum (photon) put forward by Einstein.[66]

Evidence for both wave and particulate descriptions are found in our experiences at the quantum level. And yet, the way our language is constructed, we cannot use both. This was a profound problem for both the physicist and the philosopher alike. As Holton remarks, "unhappiness with the wave-particle paradox, with being forced to use in different contexts two such antithetical theories of light as the classical wave theory and the quantum (photon) theory was widely felt.[67] As we will see, Bohr's response to these dilemmas will be quite unique.

Bohr's 1927 Como lecture, containing the foundations of the Copenhagen Interpretation, is a response to the difficulties described above. In the lecture--which aside from a few mathematical equations contained very little physics--Bohr proposes for the first time the notion of <u>complementarity</u>. What Bohr will emphasize is that the problem is not with the experimentation, not with the theory, not even with us as limited knowing agents, but rather, the problem lies in <u>language</u>. That is why the questions we ask are so important, as Heisenberg claims (cf. above). It is precisely this placing of stress on the "question asking" that makes

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[66] Niels Bohr, "The Quantum Postulate and the Recent Development of Atomic Theory" in Bohr, <u>Vol. I</u>, p. 55.

[67] Gerald Holton, "Roots of Complementarity," p. 117.

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quantum theory so conducive to a hermeneutic treatment. We will see how both Bohr and Heisenberg were consciously aware of the dialogical nature of science as they constantly remind us in their work that it is not Nature that we are privy to in scientific experiment, but "Nature responding to our mode of questioning." Determining what the "right" mode of questioning is will be crucial to our treatment of Bohr's writings. What we will see is that almost all the questions quantum physics forces us to ask of nature have something to do with a contradiction of some sort. For example, "how could it be that the same radiation that produces interference patterns, and therefore must consist of waves, also produces the photoelectric effect, and therefore must consist of moving particles?"[68] What Bohr will do is to restructure our questions to be concerned with communicating experiences of these contradictory phenomena rather than solving the puzzle. The focus will be on epistemology rather than ontology. It is precisely the nature of his response to contradiction and paradox in the form of complementarity that makes Bohr's thought not only essentially philosophical, but uniquely hermeneutic.

What I will do in the following sections is to described Bohr's responses to the above dilemmas dividing the issues in the following way: 1) The measurement problem (#'s 1 and 2 above); 2) the breakdown of classical concepts (causality);

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[68] Werner Heisenberg, Physics and Philosophy, p. 35.

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and 3) the wave-particle dualism. What we will see is how Bohr delighted at the opportunities that quantum physics provided for the philosopher. Hidden in each of the dilemmas above is a chance to rethink some epistemological problems that have manifested themselves in many other disciplines, and we will see Bohr capitalize on that opportunity time and time again. What we will likewise see is that implicit in this concern with what quantum physics enables us, or as Bohr is wont to claim "forces" us to do, is a profound statement on the connection between the physical sciences and the human sciences that is consistent with the recent "interpretive turn." The point will be made that in making the transition between philosophy and physics as smoothly (and constantly) as he does, Bohr is bringing to light a certain holism implicit in his writings that brings to the fore just these commonalities in disciplines. The task is to show how such a holism does not usher in a relativism and is compatible with a notion of realism. Perhaps most importantly, it will be shown that Bohr places the similarities in disciplines on the part of the thinker rather than the subject matter, making it consistent with the more conservative universal hermeneutic I have described in the last chapter. In that sense, Bohr's interpretation of quantum physics is consistent with my attempt to on the one hand collapse the distinction between the physical and human sciences by way of this universal hermeneutic, while at the same time maintaining a difference

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in light of the object of study itself.

Finally, I will discuss the different historical and philosophical influences on Bohr's thought to show that not only do these influences inform his work, but the reason he embraced the dilemmas in quantum theory to the extent he did was because they substantiated and confirmed his philosophical concerns. Foremost among them is the concern about language and communication. With that we will see how Bohr's philosophy of science is consistent with the interpretive turn in this post-empiricist age with its emphasis on the social dimensions of science. What I would like to show is that Bohr's lament to Thomas Kuhn in the interview on the eve of his death that no man who considers himself a philosopher truly understands what is meant by complementarity can be attributed to the fact that a full understanding depended on certain events in the course of the history of philosophy that were yet to come. Foremost among them is the assertion that we have gone beyond certain epistemological constraints.[69] It is not coincidental that this statement was made by Bohr on the (conceptual) eve of the publication of Kuhn's magnum opus[70], which would soon open the floodgate to the interpretive turn and the social dimensions of natural science. In this respect Bohr's thought will be shown to be

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[69] See the discussion of Richard Bernstein's work Beyond Objectivism and Relativism in the previous chapter.

[70] Thomas Kuhn, The Structure of Scientific Revolutions, (1962).

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prescient in its anticipation of what was to come: an understanding of the hermeneutic dimensions of natural science.

With that, we consider Bohr's response to the first of the dilemmas: namely, the measurement problem.

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(b) The measurement problem and the subject-object distinction.

First and foremost it must be restated that Bohr delighted in the revealing in the quantum paradoxes. He saw in them a chance to reexamine certain fundamental assumptions about our role not only as observers of nature, but as human knowers in general. Indeed, his very definition of natural science reflects this, as he states, "the goal of science is to augment and order our experience and deepen our understanding of the nature of which we are a part."[71] Quantum physics, by extending our experiences as it does, reveals hidden aspects of nature that might otherwise go unnoticed. These features are fundamental facts about the world--of which we are a part. It is precisely in such circumstances when our efforts to secure objectivity along traditional lines are frustrated (as they seem to be in quantum physics) that we are offered the opportunity to examine and rethink the presuppositions at work; and as a result we may be able to amend our goals.

Most importantly, Bohr embraced the difficulties encountered in trying to account for quantum phenomena precisely because they forced us to be critical of things we might otherwise take for granted or ignore not only regarding the physical world, but regarding thought in general. In

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[71] See especially Introduction to Bohr, Vol. I.

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fact, extension of our experience into the quantum domain forces us to re-examine with a more critical and less assuming attitude the very conditions for human understanding. For Bohr the dilemmas exposed by quantum theory were no dilemmas at all but rather a fortuitous opportunity to gain true understanding where we might otherwise not. As Bohr states in the preface to the first volume of his philosophical essays,

> Whatever the development in this domain may be, we have...every reason to rejoice that, within the relatively objective domain of physics, where emotional elements are largely relegated to the background, we have encountered problems capable of reminding us anew of the general conditions underlying all human understanding, which, from time immemorial, have attracted the attention of philosophers.[72]

No doubt it was statements like this that prompted Heisenberg to declare that Bohr was not really a physicist but primarily a philosopher.[73] Regardless, my claim is that the way Bohr characterizes those "conditions" for understanding is precisely what qualifies him to be placed in the category of modern hermeneutics.

Without presuming to pass judgment on the validity of Heisenberg's claim, we can maintain, however, that the quantum situation gave a physicist a chance to satisfy his deep-seated philosophical tendencies while at the same time putting forth what ended up being the most coherent and consistent

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[72] Bohr, Vol. I, p. 21.

[73] See above.

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interpretation of a most novel situation in physical theory.[74] (Interestingly, many claim the scientific advances were merely an afterthought in Bohr's work.)[75] Most importantly, the anomalous and revolutionary situations one encounters in quantum physics provide Bohr with the opportunity to address his prior concerns regarding language and communication and the role they play in our knowledge of the world. As Jorgen Kalckar states in his introduction to Niels Bohr's Collected Works, it is accurate "to describe Bohr as a born philosopher of nature, who found in physics a marvelously powerful instrument for probing into the foundations of human knowledge and man's description of the world."[76] Precisely why this instrument proved so useful will provide Bohr with a clear statement regarding the "unity of knowledge" and will shine light on the relationship between natural science and philosophy. Even before he had a clear formulation of the relationship, he recognized that in the quantum theory were the seeds for a statement about the intimate relationship between the different disciplines. As Bohr remarked very early on in his philosophical writings,

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[74] I refer to the quote by Max Jammer above

[75] Regarding the prominence of the philosophical in Bohr's thought, see especially Gerald Holton, "Roots of Complementarity." Holton remarks that even the discovery of spectral lines was of secondary importance to Bohr and merely an afterthought.

[76] Cited in Honner, The Description of Nature, p. 71.

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> Although, in the present case, we can be concerned with only more or less fitting analogies, yet we can hardly escape the conviction that in the facts which are revealed to us by the quantum theory and lie outside the domain of our ordinary forms of perception we have acquired a means of elucidating general philosophical problems.[77]

As a result, Bohr will seize the opportunity to draw striking parallels to problems we encounter in other fields of study. (This will be discussed at length below. For now we return to Bohr's reaction to the problems.)

While many physicists at the time rued the day that the quantum character of reality was revealed[78], Bohr instead delighted in the new situation. In fact he often referred to the coining of the quantum of action as "Planck's happy intuition." For Bohr it was indeed a wonderful moment in the history of both science and man's thought, as we would now gain deeper insight into the general problem of knowledge. In fact, the problems we encounter in the quantum theory will compel us to have a new, more liberal attitude toward our knowledge of the world in general. And most importantly, be open to the possibility of change in our conceptual framework.

Clearly the most fundamental philosophical issue the quantum situation brings to the fore is the problem of drawing the line of demarcation between the subject and the object in

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[77] Bohr, Vol. I, p. 101.

[78] Schrödinger was quoted to have said "If one has to go on with these damned jumps, then I'm sorry I ever started to work in atomic theory;" and Einstein's famous quip, "If this is the nature of science, I'd rather be a carpenter."

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any knowing situation. In fact, most essential of the things we might otherwise ignore in a naive pre-reflective attitude is the role of the subject in any experiential act, especially in the quest of knowledge and truth. As a result of the so-called "measurement problem," which states that in the quantum domain, any attempt to measure or observe a system will in some way disturb the system, we are forced to rethink and be critical of the classical notion of objectivity. Classical theory demands a firm line be drawn between subject and object in order to secure objectivity. The very basis of not only classical theory, but common sense encounters with the world presume an object that is somehow out there independent of the subject. When we apprehend (observe, measure, etc.) an object, we assume our apprehension is in no way altering or affecting the object. We feel confident that, (barring any unforeseen, yet corrigible problem of error in interpretation) our knowledge <u>can</u> be objective precisely because of the firm dividing line between the two. But now we have a situation where, due to limitations on our knowledge imposed by the quantum of action, we can no longer draw such a line in any absolute way. To restate the problem, in order for an experiment to take place whereby say an electron is "observed" or detected, or a particle is located, it is the case that the observation itself, or attempt at local determination will affect the experiment in such a way as to "disturb" the phenomena. This is most antithetical to the classical notion

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of observation whereby the object is somehow "out there" and a clear line of delineation can be drawn between subject and object. The simple solution, and perhaps most conservative way of eliminating the problem is to imagine an experimental arrangement where such "disturbing" does not take place. In other words, one works toward either better tools of experimentation, better arrangements, or as yet undisclosed (or "hidden") theories that will eliminate the problem. Indeed the situation where the partition line between subject/agent and object of observation is not firmly drawn will be a problem in as much as it introduces into any situation a distortive notion of subjectivity. To say that my observing something will affect it in such a way as quantum theory claims is to bring into question the very worth of the examination. Reality seems to be something we do not have access to, our experiences always clouded or distorted by our act of observation. It seems to lead to a strong Kantianism, where the noumenal is not an object of our understanding. And yet, that was not at all Bohr's interpretation.

It is precisely in this problem of measurement that the limitations of the classical ideas are first brought to light, as Bohr states,

> "...the finite magnitude of the quantum of action prevents altogether a sharp distinction being made between a phenomenon and the agency by which it is observed, a distinction which underlies the customary concept of observation and, therefore forms the basis of

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the classical ideas of motion.[79]

Note that this is in no way a limitation due to inadequate instruments. Rather it is a fact about nature. This fact forces us to examine the customary concept of observation that we uncritically accept and depend on. Bohr is cautioning against the naive view of science which classical physics to some extent supported. To ensure we are apprehending the object "as it really is" we guard against such subjective intrusion. This is the case not only in observation, but was part of the Cartesian legacy of objectivity. The classical ideal of our taking a stance apart from the world as detached observers is, in Bohr's view, necessarily limited. Because of this ineliminable interaction, any and all accounts of observation must now include the agent of observation, or the subject. By demanding that in an account of any observation we must include a description of the entire "experimental arrangement," quantum theory is introducing a feature of wholeness into our knowledge. Bohr is quick to point out that there is a lesson for us in this recognition--an epistemological lesson that we should apply to all fields of inquiry. In the 1957 preface to his second volume of philosophical essays, Bohr describes it as an "epistemological lesson which the modern development of atomic physics has given us and (which is relevant) for analysis and synthesis in

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[79] Bohr, Vol. I, p. 12.

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many fields of human knowledge."[80] As we shall see, his point will be that the quantum situation is not merely a reminder of problems encountered in other fields; more importantly, the quantum situation will provide help with possible solutions.

Taking heed of the epistemological lesson, as Bohr bids us to do, will require that we always take into account the means by which information is obtained. In other words, in any experiential situation, we can no longer ignore the role of the subject. Bohr ends his introduction to the second volume of essays (mentioned above) with the following claim:

> ...the gist of the argument is that for objective description and harmonious comprehension it is necessary in almost every field of knowledge to pay attention to the circumstances under which evidence is obtained.[81]

This emphasis on the conditions of observation is a clear introduction of contextualization, which, as we shall see, is at the heart of any hermeneutic theory. Indeed, "paying attention to the circumstances under which evidence is obtained" is precisely what hermeneutics will bid us do when it calls on us to consider the conditions surrounding any event of understanding. Objectivity can no longer be equated with the classical ideal of subject-free. Any attempt at objective description will be contextual and specific to the framework of the subject. As John Honner notes, "the general

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[80] Bohr, Vol. II, p. v.

[81] Bohr, Vol. II, p. 2.

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epistemological lesson which Bohr found to be instantiated in quantum theory was that the idealized objectivity of classical physics was itself open to critique: any descriptive language belongs to the framework of the subject, and object and subject cannot be so sharply distinguished."[82] And yet, we can still lay claim to objectivity. It is just an objectivity that includes the subject. Once again, experience/observation is contextual and the subject is ineliminable.

While many physicists saw this situation one encounters in quantum theory as a limitation on either our measuring instruments or on our theories in general, Bohr took this as an opportunity to reexamine just what we mean by "observation" and what the epistemological consequences will be. In fact, as Bohr is quick to point out, the consequences of the measurement problem bear a deep logical similarity to difficulties we often encounter in other fields of inquiry. As he states quite early on in his writings,

> The impossibility of distinguishing in our customary way between physical phenomena and their observation places us, indeed, in a position quite similar to that which is so familiar in psychology where we are continually reminded of the difficulty of distinguishing between subject and object.[83]

Bohr recognized that this was the most profound and essential of philosophical issues, as he noted, "the relationship between subject and object forms the core problem of

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[82] John Honner, Description of Nature, p. 147.

[83] Bohr, Vol. I, p. 15.

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knowledge".[84] Once we question the relationship between the subject and object and compromise their autonomy, we seem to make the issue of objectivity itself suspect. The question we must now ask is, do we also compromise truth? As was stated above, to ensure we are apprehending the object "as it really is" we usually guard against any subjective intrusion. Quantum theory, at least in the domain of physics, seems to decide matters in favor of both the anti-realist and the relativist. Further, if we are to extend this lesson into all other fields of inquiry, as Bohr bids us, must we be doomed to a philosophical relativism? It will be shown that this is neither the intention of Bohr nor a consequence of the hermeneutic theory that his philosophy resembles. For the moment, we return to this pervasive problem of the relationship between subject and object.

It is clear that this problem, most apparent in psychology and epistemology, is one that preoccupied Bohr. He saw an immediate similarity between the measurement problem in quantum physics and the attempt to consider the subject as an object of study. As he describes it,

> The epistemological problem under discussion may be characterized briefly as follows: For describing our mental activity, we require, on one hand, an objectively given content to be placed in opposition to a perceiving subject, while, on the other hand, as is already implied by such an assertion, no sharp separation between object and subject can be maintained, since the perceiving

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[84] Ibid, p. 117.

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subject also belongs to our mental content.[85]

The problem encountered in psychology, of turning inward to examine mental content comes about because the "I" is part of what it is trying to describe. Similarly, in quantum theory, the subject becomes part of the entire phenomenon in as much as it plays a role in the constituting of it. In fact by the very term "phenomenon" Bohr understood an inclusion of the experimental arrangement or subject. The experimental arrangement thus becomes part of the phenomenon it was set up to observe. Therefore, a sharp separation of the two becomes impossible.

We recall that while Bohr originally made the claim that the measuring of a particle "disturbs" it, by 1937 he had abandoned describing the situation in such a way. Bohr recognized that by stating that the phenomenon is somehow "disturbed" by the measurement he seemed to indicate that there is an independent reality outside of the measuring that we do not have access to. That would seem to suggest that were the situation otherwise, perhaps if our instruments were better, or, to paraphrase Kant, if there were a consciousness "other than ours," then perhaps we could apprehend the phenomenon in its true "undisturbed" state. This is not at all what Bohr intends. In fact by 1937 he cautions us against using such a description, as he states,

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[85] Niels Bohr, "The Quantum of Action and Description of Nature," in Bohr Vol. I, p. 96.

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> In this connection I warned especially against phrases, often found in the physical literature, such as "disturbing of phenomena by observation" or "creating physical attributes to atomic objects by measurements." Such phrases, which may serve to remind of the apparent paradoxes in quantum theory, are at the same time apt to cause confusion, since words like "phenomena" and "observation," just as "attributes" and "measurements," are used in a way hardly compatible with common language and practical definition.[86]

Instead of "disturb," Bohr seems to be looking for something akin to Husserlian "intentionality," whereby the subject intends or constitutes the object as an object of study. In that respect the object depends on the subject. In fact Bohr seems to be warning against the use of the term "disturb" because it invokes the same naturalistic attitude that Husserl so often warns against.[87] Husserl criticizes the 'natural attitude' of the positive sciences for taking the objective status of reality for granted. For Husserl meaning is not something that objectively exists, but a relationship of consciousness. In that respect, the phenomenological attitude claimed to overcome the traditional extremes of idealism and realism since both deny the intentional rapport between consciousness and world. While not quite as concerned with the mutuality of constitution, Bohr does nonetheless seem to appreciate the intentional nature of the quantum object and

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[86] Bohr, Vol. II, p. 64.

[87] See especially, Edmund Husserl's, The Crisis of European Sciences and Transcendental Phenomenology (Evanston: Northwestern University Press, 1970).

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its dependence on the subject.[88] For Husserl as well, subject and object are never separate. Furthermore, we will see how Bohr surpasses Husserl much the way Heidegger and Gadamer do in emphasizing the role of communication and the dialogic conception of language.[89]

Once again, the measurement problem brings to light the oldest of philosophical considerations: the problem of "objectivity," as Bohr states,

> ...the very recognition of the limited divisibility of physical processes, symbolized by the quantum of action, has justified the old doubts as to the range of our ordinary forms of perception when applied to atomic phenomena. Since in the observation of these phenomena, we cannot neglect the interaction between the object and the instrument of observations, the question of the possibility of observation again comes to the foreground. Thus we meet here, in a new light, the problem of the objectivity of phenomena which has already attracted so much attention in philosophical discussion.[90]

The concern, or philosophical problem which rears its head is that of the "objectivity of phenomena," a special case of the age-old problem of objectivity in general. What role does the subject have in the constitution of the object? If there is

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[88] There are other similarities between Bohr's thought and that of Husserl, such as the way Bohr seems to invoke the Husserlian epoché with respect to the ontological status of atomic objects. This remains the topic of another study. It nonetheless remains interesting that Bohr likewise shares with modern hermeneutics the phenomenological point of departure.

[89] Even though in the Crisis, Husserl himself seeks to overcome the dangers of solipsism by showing how all subjective consciousness is grafted upon an intersubjective community, Richard Bernstein points out that Husserl nonetheless falls prey to the same subjectivism he claims to be trying to overcome. See Beyond Objectivism and Relativism.

[90] Bohr Vol. I, p. 93.

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more than a nominal role, then is the very notion of "objectivity" in jeopardy?

As noted above, Bohr wants to take this lesson, gleaned from quantum physics, and use it in other domains of human thought. While this situation whereby the line cannot be so firmly drawn is quite new to physical science, it is a problem that is certainly not new to philosophy. Interestingly enough, in this respect, Bohr finds company in the thought of Eastern thinkers who have often considered our position in the world along these lines. Bohr tells us that,

> For a parallel to the lesson of atomic theory regarding the limited applicability of such customary idealizations, we must in fact turn to quite other branches of science, such as psychology, or even to that end of epistemological problems with which already thinkers like Buddha and Lao Tse have been confronted, when trying to harmonize our positions as spectators and actors in the great drama of existence."[91]

Interestingly, Bohr, as well as many of his colleagues, will attribute to the more Eastern way of thinking a keener appreciation of dialectics which seems to be requisite for an understanding of his interpretation of quantum theory.[92] However, Bohr is quick to point out that by invoking the thought of Eastern thinkers, as he often does, and by infusing quantum physics with metaphysical claims, he is by no means introducing into physics a mysticism that is "foreign to the spirit of science." But, as we shall see, toward the end of

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[91] Bohr Vol. II, p. 20.

[92] This will be discussed below.

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his thought Bohr comes to embrace the mystical element as being an essential part of any science.

This unique position of being both actors and spectators in the world should be at the center of our thoughts, according to Bohr, and is a sentiment he often repeats in his writings. In fact bringing to light this realization often serves as an excuse for Bohr's delving into domains which seem out of character for a physicist, as he remarks, "that a physicist may perhaps be excused on the ground that the new situation in physics has so forcibly reminded us of the old truth that we are both onlookers and actors in the great drama of existence."[93] And his point is that we should be no less aware of that fact when we do science, than when we are working in any other field. The philosophical concerns are inescapable. As Emile Meyerson would claim, "man does metaphysics as he lives and breathes."

In psychology there are an abundance of examples and situations that bring to light the arbitrariness of the subject-object distinction. In a wonderfully vivid example drawing on every day life, Bohr notes the following:

> "One need only remember here the sensation, often cited by psychologists, which every one has experienced when attempting to orient himself in a dark room by feeling with a stick. When the stick is held loosely, it appears to the sense of touch to be an object. When, however, it is held firmly, we lose the sensation that it is a foreign body, and the impression of touch becomes immediately localized at the point where the stick is

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[93] Bohr Vol. I, p. 119.

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touching the body under investigation."[94]

This tellingly phenomenological description is reminiscent of accounts of perception often found in the work of Merleau-Ponty[95] which highlight the same arbitrariness of the separation line (and are further evidence for the Husserlian point of departure).

While this situation is often encountered elsewhere, as Bohr has been pointing out, it remains the case that in the domain of natural science, (the so-called "exact sciences"), where all attempts at objective description are made without reference to the subject, this is quite a novel encounter. Indeed, Bohr stresses that this moment in physics is quite unprecedented. Even Einstein's relativity theory, which Bohr often praised for its bold iconoclasm and liberal attitude toward our customary concepts depended on the assumption that "it is possible to discriminate between the behavior of natural objects and the questions of their observations."[96] Bohr comments on the novelty of encountering this familiar situation in the domain of physics as follows:

> We are here faced with an epistemological problem quite new in natural philosophy, where all description of experiences has so far been based upon the assumption already inherent in ordinary conventions of language, that it is possible to distinguish sharply between the

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[94] Bohr, Vol. I, p. 99.

[95] See especially Maurice Merleau-Ponty, Phenomenology of Perception, translated Colin Smith (London: Routledge & Keagan Paul, 1962).

[96] Bohr Vol. II, p. 19.

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behavior of the objects and means of observation.[97] This statement, written in 1938, is much clearer on the fact that this presupposition we are questioning is reflected in our language. As we shall see, from that point on, the focus of Bohr's concern will be on language and how it shapes our understanding--both in its power and its limitations.

Most physicists close to Bohr, as well as philosophers who have studied his works, attribute this concern on his part for the inability to draw a definitive line between the subject and the object not exclusively to the situation encountered in quantum physics, but to prior concerns about the nature of language and the self. The source of Bohr's interest in this problem goes back to his encounter with the work of a Danish poet and philosopher by the name of Poul Martin Møller. Bohr regarded Møller's work so essential that reading it became a right of passage for any physicist working in the Copenhagen School under Bohr's direction. As Léon Rosenfeld, close colleague and often champion of the Copenhagen interpretation notes, "everyone of those who came into close contact with Bohr at the Institute, as soon as he showed himself sufficiently proficient in the Danish language, was acquainted with the little book: it was part of his initiation."[98] In his essay entitled "The Unity of Human

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[97] Ibid, p. 25.

[98] Léon Rosenfeld, "Niels Bohr in the Thirties," in Rozental ed., Niels Bohr: His Life and Work as seen by his friends and colleagues, p. 121.

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Knowledge" Bohr himself describes the importance of Møller's work. He tells us that

> In his novel, called The Adventures of a Danish Student, the author gives a remarkably vivid and suggestive account of the interplay between the various aspects of our position, illuminated by discussions within a circle of students with different characters and divergent attitudes to life.[99]

At one point in the novel, one of the students, referred to as the licentiate, and who is "addicted to remote philosophical meditations detrimental to his social activities" is trying to account for his inability to seek out practical employment. He describes his reflections as follows,

> My endless enquiries make it impossible for me to achieve anything. Furthermore, I get to think about my own thoughts of the situation in which I find myself. I even think that I think of it, and divide myself into an infinite retrogressive sequence of "I'"s who consider each other. I do not know at which "I" to stop as the actual, and in the moment I stop at one, there is indeed again an "I" which stops at it. I become confused and feel a dizziness as if I were looking down into a bottomless abyss, and my ponderings result finally in a terrible headache.[100]

While the difficulty involving such searches for the "ultimate subject" are by no means new to philosophical or existential discussions, what is quite novel is the attempt by Bohr to compare such philosophical musings with a situation encountered in physical science. This description of the fact that "any attempt at exhaustive description of the richness of

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[99] Niels Bohr, "The Unity of Human Knowledge" in The Philosophical Writings of Niels Bohr, Vol. III, "Essays 1958-1962 on Atom Physics and Human Knowledge" (Woodbridge CT: Ox Bow Press, 1987) p. 13. thereafter Bohr, Vol. III.

[100] Ibid.

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conscious life demands in various situations a different placing of the section between subject and object"[101] is for Bohr a reminder of the "measurement problem" encountered on the quantum level. As he states,

> Quite apart from the fine humour with which the story is told, it is certainly not easy to give a more pertinent account of essential aspects of the situation with which we all are faced.[102]

Bohr's point was that only when we consider such problems as encountered in the search for the "ultimate subject" will we truly understand and appreciate the rich implications of the quantum theory. The point is that just as (due to the measurement problem) we need to abandon a firm placing of the line of demarcation in physics, so too, to resolve these dilemmas encountered in psychology and in epistemology, we will need to do the same. Bohr's claim is that we should be aware of these things. He is grateful to the quantum situation for forcing the philosophy on us, as we are called upon to rethink what happens when we observe something. Consequently, we will be forced to rethink what takes place when we understand something--and, as we will see (most importantly), what takes place when we communicate to others what we have experienced.

In an address entitled "Light and Life" delivered in 1932 to an assembly of scientists on the topic of the beneficial

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[101] Ibid.

[102] Ibid.

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effects of the use of light in the cure of diseases, Bohr states the following:

> Indeed the necessity of considering the interaction between the measuring instruments and the object under investigation in atomic mechanics exhibits a close analogy to the peculiar difficulties in psychological analysis arising from the fact that the mental content is invariably altered when the attention is concentrated on any special feature of it.[103]

This is quite similar to the situation in hermeneutics whereby any attempt at understanding a text, or text analogue, will alter both the subject and the object. Both are transformed in and through the attempt at understanding. We are alerted once again to the impossibility of isolating the "ultimate subject" as well as the "objectively given" object.

It is precisely the measurement problem in quantum physics that alerts us anew to the ineliminable role of the subject in any situation. Subject and object are neither autonomous nor clearly separable. Rather, there is a mutual constituting of subject and object, in an Husserlian sense. Hermeneutically speaking, this is a striking reminder of the fact that in any interpretive (read experimental) act, both the subject and object are in some way transformed.

Just as for Kuhn and post-empiricist philosophers of science, objectivity cannot be secured by way of "pure" theory-free and prejudice-free observation, we now have a practical example of the very same situation. On the experimental level, we can no longer be assured of objective

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[103] Bohr, Vol. II, p. 11.

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(read subject-free) observations. In philosophy we have seen this abandoning of the demarcation line between subject and object come to fruition at the hands of Hans-Georg Gadamer. With that we turn to a discussion of the hermeneutic elements in Bohr's thought.

While Bohr's primary concern seems to be with the similarities the situation encountered in quantum theory bears to situations encountered in psychology and epistemology, we can draw those same similarities with respect to a hermeneutic approach in philosophy. The subject-object distinction is at the very heart of philosophical hermeneutics. Indeed modern hermeneutics understands itself as a critique both of the notion of a non-contingent autonomous subject that can be separated from an object and an independently existing non-contextual object.

In his own work, Gadamer is interested primarily in effacing the dominant modern epistemological-metaphysical paradigm of the subject-object split. The first lesson we learn is that such a split can no longer be firmly made. There is a mutual constituting and transforming of the subject and object in each interpretive act. Furthermore, Gadamer claims, if you start with and accept this firm subject-object split, then truth must be representational. Such truth is, however, limited to the realm of natural science (on the old view of science). In order to destroy the monopoly on truth that science claims, Gadamer seeks to show that there is

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another kind of truth happening in works of art. Truth and Method begins precisely with an elucidation of this other kind of truth. Gadamer goes on to criticize what he calls the mere aestheticism and subjectivization of art. But most fundamental to this project is the elimination (eventually in all fields) of the firmly drawn subject-object split.

Quite similarly, we can claim that on the old representational picture of truth, quantum observations likewise cannot claim truth value since in Bohr's interpretation we cannot picture the quantum situation (the renunciation for the demand of pictorial representation will be treated fully in the next section). Bohr's profound insight here was that in order to restore a notion of truth, he must raze the Cartesian structure and eliminate the picture theory of truth that classical theory so depended on. We will see in the discussion of "Realism and Truth" below, the striking similarities Bohr's conception of truth has to Gadamer's countenancing of Heideggerian aletheia.

In commenting on being open to the truth that takes place in the work of art, Gadamer describes a "to and fro" movement between us and the work. It is not as if we are somehow detached or disinterested spectators simply looking upon "objects" and seeking to purify our "aesthetic consciousness" by "aesthetic differentiation." Rather, there is a to-and-fro movement, a participation that characterizes our involvement with the work of art. In a similar vein, Bohr remarks on the

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subject's involvement with the "work" (in this case the experiment). The subject participates in as much as the phenomenon must now include a description of the experimental arrangement including the instrument-cum-subject.

In addition, Bohr speaks of a similar kind of "to-and-fro" movement in terms of a balancing between analysis (theory) and synthesis (observation). He tells us that "our only way of avoiding the extremes of materialism is the never ending endeavor to balance analysis and synthesis." Remarking on this balance, Honner notes that "neither theory nor fact has privileged status. Instead, science is engaged in a to-and-fro process which rests on the assumptions that the world exists and that we can communicate unambiguously about that world."[104]

Modern hermeneutics is a contextualist theory; any truth claim is not only dependent on an implicit context of meaning, but likewise is perspectival. Similarly, by emphasizing the importance of the entire experimental situation, Bohr is likewise emphasizing the contextual nature of all experience, and by fiat, all understanding. Indeed he recognizes this very fact when he states, remarking on this new epistemological lesson,

> From these circumstances follows...the relative meaning of every concept, or rather, every word, the meaning

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[104] John Honner, The Description of Nature, p. 149.

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> depending upon our (arbitrary)[105] choice of view point...[106]

The quantum situation is yet another reminder of the fact that we always experience/understand reality from some perspective and we must take into account precisely what that perspective is. And yet that needn't require us to give way to an extreme relativism. Despite the perspectival nature of all understanding, we are nevertheless still in contact with reality; it is just reality from a specific vantage point. Such reality does not, however, lie outside the different perspectives. But rather, is the amalgam of different perspectives.

In his recent defense of the Gadamerian project[107], Richard Bernstein goes on to show how this time-honored tradition of drawing a firm dividing line between subject and object is responsible for most epistemological maladies philosophy encounters, especially the "specter of relativism" that looms large in any hermeneutic theory. He sees this problem as a vestige of what he calls "Cartesian anxiety." According to Bernstein, only if we accept some version of Cartesianism which requires the autonomy of subject and object, does the exclusive disjunction of objectivism or

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[105] The emphasis on arbitrariness is dropped in Bohr's later writings when he is more clear on the "realist" element in his thought.

[106] Bohr, Vol. I, p. 96.

[107] Richard Bernstein, Beyond Objectivism and Relativism.

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relativism become intelligible. But if we question, expose, and exorcise Cartesianism, then the very opposition loses its plausibility. Incidentally, Bernstein points out that Kuhn fell prey to charges of irrationalism precisely because the discussion was still infected with the legacy of the Cartesian Either/Or.

This is precisely what Bohr was doing in questioning the dividing line between subject and object. By doing so he compromised the very foundation of not only an independent object, but the Cartesian prejudice-free subject as well. In a very telling remark, Bohr hints at this realization that we have gone beyond such constraints when he declares that we must abandon the search for the ultimate subject. Bohr states that

> Since, in philosophical literature, reference is sometimes made to different levels of objectivity or subjectivity or even of reality, it may be stressed that the notion of an ultimate subject as well as conceptions like realism and idealism find no place in objective description as we have defined it.[108]

Thus Bohr's recognition, in concert with Bernstein, is that we have gone beyond certain fixed categories. By redefining "objectivity" in terms of the subject, and with reference to communication, (as we shall see in the next section), Bohr calls on us to renounce the traditional categories we often

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[108] Niels Bohr, "Unity of Knowledge" (1954), in Bohr, Vol. III, p. 79. Likewise, in 1960 in "The Unity of Human Knowledge" Bohr claims "It is evident that the search for an ultimate subject is at variance with the aim of subjective description, which demands the contraposition of subject and object," in Bohr, Vol. III, p. 14.

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find ourselves trying to accommodate. We have moved beyond them.

On a final note, it can be claimed that the concern of Gadamer's entire philosophical career has been to overcome the positivist hubris of assuming that one can develop an "objective" knowledge of the phenomena with which we are concerned. If by "objective" we read free from prejudice, and in effect, opposed to "subject" then as we have seen, the quantum situation is another reminder that this is an impossibility and contributes to the realization that we have gone beyond such limitations. But if we redefine "objective" the way Bohr does, to mean "unambiguous communication" then indeed we have "objective" knowledge so long as we are engaged in (productive) dialogue. But we must remember that given the very nature of dialogue--the fact that it is open-ended and continues, and therefore always subject to revision, there will be no closure on the "objective description." Judgments are open to revision as new evidence comes to hand. As Joel Weinsheimer declares in his explication of Truth and Method,

> The universe of discourse, like the physical universe, is constantly expanding. Thus the hermeneutic circle, in which truth is understood as the conclusive reconciliation of whole and part, might better be conceived as a hermeneutic spiral, in which truth keeps expanding. That is, the whole truth never is but always to be achieved.[109]

It is clear that Bohr appreciated this sentiment. Not

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[109] Joel C. Weinsheimer, Gadamer's Hermeneutics (New Haven: Yale University Press, 1985), p. 40.

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only will we see his appreciation of the disclosive nature of truth, but his recognition that truth can always be altered. He often warns us to expect alterations in our conceptual schemes, and alerts us to the fact that the intellectual landscape will always change.

With that we enter into a discussion of Bohr's redefinition of objectivity and his concern with language.

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(c) Language and Objectivity

While it might seem that such inclusion of the subjective would prohibit any conception of objectivity, that is not the case with Bohr's thought. It will, however, require a redefinition of precisely what we mean by "objectivity." Throughout his work, Niels Bohr identifies "objectivity" with "unambiguous communication." We are assured of an objective account if we have communicated unambiguously to others what we have experienced. This redefining of objectivity in terms of communication and dialogue is not surprising, given the prior preoccupation Bohr had with language, including an appreciation for its essentially dialogical nature. Therefore, before we can look closely at just what Bohr means by "unambiguous communication" we must look at these preoccupations with language to see how they influenced his philosophy. What we shall see is that Bohr's understanding of language and appreciation of the role it plays in our cognitive lives betrays a distinctly hermeneutic attitude. In fact, many of his claims about language will be strikingly similar to some of the things Gadamer has stated in Truth and Method.

In his contribution to a collection of essays written by Bohr's dearest friends and colleagues, Léon Rosenfeld wrote the following:

> Since his early youth, Bohr had been preoccupied by this problem of the ambiguity of language, and had with sure

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> intuition grasped its essentially dialectical character.[110]

There is no doubt that language fascinated Bohr. In fact, elsewhere Rosenfeld claims that the preoccupation with language was at the very heart of Bohr's philosophy. He notes that "it is remarkable that Bohr's first preoccupation with philosophical problems did not arise from his physical investigations, but from general epistemological considerations about the function of language as a means of communicating experience."[111] Communication and dialogue were at the very core of Bohr's philosophical concerns. What is distinctive about Bohr's preoccupation with language was an essential appreciation of the dialogical nature of language. As John Honner has noted,

> A curious characteristic of Bohr's way of doing science was that he could only function, it seemed, in dialogue with his colleagues and students. It was essential for him to spend at least a portion of his time thinking out loud with others.[112]

In order to appreciate fully the role that language and dialogue play in his thought, we need to consider the atmosphere in which Bohr was first exposed to philosophy.

Niels Bohr's father, Christian Bohr was professor of

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[110] Léon Rosenfeld, "Niels Bohr in the 30's," p. 120.

[111] Léon Rosenfeld, "Niels Bohr's Contribution to Epistemology" in Selected Papers of Léon Rosenfeld, edited by R.S. Cohen and J.J. Stachel. Boston Studies in the Philosophy of Science Vol. XXI, ed. by Robert S. Cohen and Marx W.. Wartofsky (Boston: D. Reidel Publishing Co, 1979), p. 526.

[112] John Honner, The Description of Nature, p. 170.

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physiology at the University of Copenhagen and deeply involved in the mechanism versus vitalism debate that had erupted around the turn of the century.[113] While Niels was growing up, an informal discussion group often assembled at the home of his father to engage in philosophical discussions. Regular participants in the group included the elder Bohr, the physicist Christian Christiansen, the philologist Hans Thomsen, and perhaps most importantly, the philosopher Harald Høffding. This group, which referred to themselves as "Eliptika," would often meet to discuss various philosophical issues. Most important of topics discussed was the relationship between the various philosophical problems and the current advances being made in the natural sciences. Bohr himself has attested to the profound influence these Socratic-like discussions had on him, as he was often permitted to stay and listen, playing a role somewhat akin to the "malleable youth," as Hegel might say. It was in listening to these meetings that Bohr was first enlightened to the power of dialogue, something he may have been able to glean from his father. In describing the elder Bohr, Høffding once remarked, "Christian Bohr...was a keen worshipper of Goethe. When he spoke of practical situations or views of life, he liked to do

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[113]In fact, many find the seeds for complementarity in a desire to harmonize the dichotomous dilemma in which his father was involved.

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so in a dialectical manner."[114]

Thus, Bohr's first exposure to philosophy was through dialogical encounters. It was here that he first learned of the power and richness of dialogue, and the importance of communication. This appreciation for dialogue and for the kind of understanding dialogue brings about was carried over into his own work, as many who worked with him, especially at the Copenhagen Institute would attest.[115] It is well documented that conversation was the way by which Niels Bohr developed his thoughts. As John Wheeler has noted, "who ever saw Niels Bohr make progress with an idea except in dialogue or dictation or sudden revelation out of the depths of the subconscious?"[116]

It is now easy to see how Bohr would make the connection between objectivity and communication. From the start his conception of knowledge had a social aspect to it, precisely by virtue of this concern with dialogue. This is perhaps the most glaringly hermeneutic aspect of Bohr's thought. In addition, by redefining objectivity in terms of unambiguous communication, Bohr is recognizing the social dimensions of science recently emphasized in contemporary philosophy of

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[114] Gerald Holton, "The Roots of Complementarity," p. 143.

[115] See especially Rozental, Rosenfeld, Heisenberg, Klein, Jammer, Pauli, and Pais, among others.

[116] John Wheeler, "Niels Bohr, The Man", Physics Today 10/1985, p. 68.

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science.[117] As he himself has stated,

> The argument is simply that by the word "experiment" we refer to a situation where we can tell others what we have done and what we have learned and that, therefore, the account of the experimental arrangement and of the results of the observations must be expressed in unambiguous language with suitable application of the terminology of classical physics.[118]

This concern for the communicating of results is quite consistent with more recent attempts by people like Kuhn and Feyerabend to emphasize the social dimensions of science. In fact, in his introduction to a recent collection of essays on that very same topic, Ernan McMullin makes the exact same point.[119]

By redefining objectivity in terms of "unambiguous communication" Bohr has opened the door to hermeneutic concerns. After all, communication requires the conveying of meaning between people, the sharing of experience and language, and ultimately will involve interpretation. Further, in order for communication to be successful, there must be a consensus. Gadamer makes this very same claim when he holds that understanding culminates in Verständigung--a coming to an understanding or consensus. In Truth and Method Gadamer notes that,

> Understanding (Verständnis) is first of all agreement (Einverständnis). So human beings usually understand one

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[117] Ernan McMullin, Martin Hollis, Steve Woolgar, etc.

[118] Bohr, Vol. II, p. 39.

[119] See Ernan McMullin, ed., The Social Dimensions of Science (Notre Dame: University of Notre Dame Press, 1992).

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> another immediately or they communicate (sich verstandigen) until they reach an agreement. Reaching an understanding (verständigung) is thus always reaching an understanding about something.[120]

Along similar lines, stressing this need for consensus, Bohr states the following,

> Science is the observation of phenomena and the communication of the results to others, who must check them. Only when we have agreed on what has happened objectively, or on what happens regularly, do we have a basis for understanding.[121]

Thus, for Bohr as well, understanding culminates in consensus. In fact, this statement bears a striking resemblance to a remark made by Karl-Otto Apel. In his discussion of critical hermeneutics, Apel declares that

> A natural scientist, as solus ipse, cannot seek to explain something for himself alone. And in order to know what he should explain, he must have come to some agreement with others about it.[122]

This emphasis on consensus is reflected not only in the way Bohr worked, but in his general concerns about both language and knowledge as well. Indeed, Bohr recognized that language itself has a social dimension and depends on dialogue. In Physics and Beyond, Heisenberg quotes Bohr's assertion that,

> ...speech, and with it thought, is an ability which--in contrast to all other physical capacities--does not

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[120] Gadamer, Truth and Method p. 158; see esp. Georgia Warnke, Gadamer: Hermeneutics, Tradition and Reason (Stanford: Stanford University Press, 1987).

[121] Quoted by Werner Heisenberg, "Discussions About Language," in Physics and Beyond, p. 130.

[122] Karl-Otto Apel, Towards a Transformation of Philosophy quoted in Understanding and Explanation, translator's intro., p. xviii.

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> develop within individuals but between individuals. We learn our speech from others. Language is, as it were, anew spread out between people, a net in which our thoughts and knowledge are inextricably enmeshed.[123]

When one learns a language, one becomes part of a tradition, one obtains a horizon of interpretation, and it is in and through such that one gains understanding (through a fusion of horizons, cf. above). In fact, this emphasis on consensus is precisely what ensures objectivity and guards against "subjective illusion" for both Bohr and Gadamer. Remarking on Bohr's penchant for engaging in dialogue, Honner notes that "perhaps he realized that it was in this way that the otherwise subjective intuition fulfilled his own criteria for objectivity."[124] This is precisely Gadamer's point. Dialogue prevents subjective illusion in as much as when we actively engage in dialogue we are open to the possibility that our position is to be amended in and through the dialogue. It requires a sensitivity and openness to critique. And indeed this can only occur in and through an encounter with another.

And yet mere consensus is not enough. Knowing how to use words, knowing the rules of the game is not enough to ensure objectivity. There has to be some contact with reality. Words must be anchored in reality in some way. Mere words are not enough. (That is why Bohr rejected the positivist

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[123] Werner Heisenberg, Physics and Beyond, p. 138.

[124] John Honner, The Description of Nature, p. 170.

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project. Despite the fact that he is often placed in the company of positivists, he was adamantly opposed to much of the positivist agenda. Bohr's opposition to positivism will be discussed below in the section on "Truth and Reality.") In a wonderful story, (that as far as I can tell has never been mentioned in any of the literature), Bohr emphasizes the importance of reality when it comes to language games. In his work Physics and Beyond, Heisenberg tells the story of a skiing trip on which he, Bohr, Pauli, and a few others had gone. Every evening the group played cards together; while playing they often mused about the significance of "bluffing" and the persuasive power of language when one is attempting to bluff. In fact, at one point when the physicists set down to play their poker game, Bohr made the odd suggestion that they play without cards. Perhaps language would be enough, since language, as a tool of persuasion, was such a powerful device in determining the winner. It was as if the cards didn't matter any more. Whoever was most convincing (in his bluff) would win. Heisenberg tells us the attempt was indeed made, but was unsuccessful. Bohr, upon further reflection, accounted for the failure in the following way:

> My suggestion was probably based on an overestimate of the importance of language; language is forced to rely on some link with reality. In real poker one plays with real cards. In that case, we can use language to 'improve' the real hand with as much optimism and conviction as we can summon up. But if we start with no reality at all, then it becomes impossible to make

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credible suggestions.[125]

Thus, pace Schopenhauer, we do not create reality. Words can gloss and enhance it, but they must have their moorings in reality. We may depend on language for understanding of reality, but language is a result of the play between word and world. Our language is thus somehow anchored in reality. Mere words without a reality would be fruitless, just as the card game without the cards would be pointless. In that case (where reality did not matter) someone like Stanley Fish would be right and theory would be glossing over theory, and Quine would be right about words taking their meanings from other words. But that could not explain any kind of success that either our conversations have, or more importantly, that science has. And yet, anchoring words in reality needn't lead us into a naive realism. (The alternative will be the "metaphoric realism" I have mentioned at the outset.)

Another aspect of language that so intrigued Bohr and which makes his understanding distinctly hermeneutic is his appreciation of the inescapability of language. Indeed, for Bohr, in order to understand the quantum situation, in order to make sense of and impose order on what is observed at the quantum level, one must be able to put into words--using classical concepts of everyday life--what we have experienced so that it can be understood by others. In seeking understanding, the point is to organize the elements of our

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[125] Werner Heisenberg, Physics and Beyond, p. 139.

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experience in such a way so as to make them coherent and consistent, and most importantly, communicable. Given the anomalies in the quantum domain, to do this most effectively and "unambiguously" will require the new conceptual framework of "complementarity," (which will be treated below).

In addition to the inescapability of language, Bohr had a clear appreciation for language as the medium through which we understand--what Gadamer refers to as die Mitte. Language is not an instrument or tool we use, but rather, the medium through which we understand. As Gadamer often notes, "Being that is understood is language," and "Language has its true being only in conversation, in the exercise of understanding between people."[126]

Language is inescapable. In as much as objectivity depends on communication, for Bohr, it likewise depends on language. This is why the formalism was not enough. Bohr recognizes not only the inescapability of language, but the essential nature of language as dialogue, and perhaps most importantly the fact that our very 'linguisticality' and 'finitude' make it impossible for us to escape the linguistically mediated nature of our contact with reality, and the necessarily perspectival and limited understanding this engenders. In other words, understanding can always be enriched as dialogue continues.

Talk or dialogue, according to Gadamer, is not an

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[126] Gadamer, Truth and Method, p. 404.

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incidental condition of inquiry; it is the very life of inquiry, discovery and truth itself. No one appreciated this more than Bohr. According to Gadamer, one can make the claim (borrowing from Heidegger), that language "has us;" it is the condition of our being. There is a striking sense in which Bohr understood this as well. In his work titled Quantum Physics and the Philosophical Tradition, Aage Petersen, a close colleague of Bohr's, recounts a discussion where Bohr was forcefully stressing the primacy of language. In a friendly debate regarding the role of language in the practices of the physicist, Bohr remarked,

> Ultimately we human beings depend on our words. We are hanging in language.[127]

Petersen tells us that when it was objected that reality is more fundamental than language and lies beneath language, Bohr replied,

> We are suspended in language in such a way that we cannot say what is up and what is down.[128]

This notion, often repeated by Bohr, that we are "suspended in language" is reminiscent of assertions by Heidegger that "language is the house of Being" and Gadamer that we have our being through language. In this same spirit Bohr too recognizes that language somehow "has us." It is much more than a tool; much more than something we possess. Remarks

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[127] Aage Petersen, Quantum Physics and The Philosophical Tradition, (Cambridge: M.I.T. Press, 1968), p. 188.

[128] Ibid.

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like this on the part of Bohr are evidence of his awareness of language as a medium or Mitte through which we not only understand, but through which we exist. We understand by communication, and yet we are somehow "suspended" in this medium of communication. We are beholden to language.

Further, we will never know all there is to language. Words are much richer than any momentary knowledge or usage of them can convey. We recall that Gadamer makes the claim that every expression brings with it the "circle of the unsaid" or the "infinity of the unsaid."[129] In that respect, every utterance points beyond itself and can convey more than intended. Words bring with them much more than is intended. Along similar lines, in a discussion regarding the importance of language, Bohr claims that,

> Of course language has this strange, fluid character. We never know what a word means exactly, and the meaning of our words depends on the way we join them together into a sentence, on the circumstances under which we formulate them, and on countless subsidiary factors. If you read the American philosopher William James, you will find that he has described it all most accurately. He says that, though our minds may seem to seize on only the most important meaning of a word we hear spoken, other meanings arise in its darker recesses, link up with different concepts and spread into the unconscious. That happens with everyday speech and a fortiori with the language of the poets. To a lesser extent, it applies to the language of science as well. Particularly in atomic physics, nature has taught us that some of our most trusted concepts have strictly limited application. You have only to think of position and velocity.[130]

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[129] See especially Hans-Georg Gadamer, Philosophical Hermeneutics.

[130] Quoted by Heisenberg in Physics and Beyond, p. 134.

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This fact that language is much richer than we know, that the meanings of words cannot be fully disclosed, seems to make "unambiguous communication" a near impossibility--a wonder, perhaps. If we never truly know the meanings of words, how will we be able either to communicate to others or properly interpret what others have communicated to us? This remains a problem only if by "unambiguous communication" we understand univocal or verifiable. This was not Bohr's intention. By calling for unambiguity, Bohr's intention is <u>not</u> to champion positivist attempts at eliminating unverifiable claims. Nor is ambiguity eliminated by fixing the meanings of the terms. As we saw, this is not possible. Words will always mean more than any context indicates. Again, they bring with them Gadamer's "circle of the unsaid." In fact, Rosenfeld has noted that for Bohr, as soon as you fix the meanings of terms you have betrayed (in the negative sense of the term) complementarity. So what does Bohr intend by "unambiguous?"

Initially what Bohr means by "unambiguous" (although he himself never makes this clear) is free from logical contradiction. That is why he needs to formulate the new conceptual framework of "complementarity" to avoid logical contradiction in description of the quantum situation. (This will be discussed fully in the section on complementarity below). But later on in his writings, one gets the sense that for Bohr something has been communicated unambiguously if the communication is effective and productive. (There is a

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pragmatic element in Bohr's thought that will become more apparent in the discussion of his conception of "truth" below). In fact, one can replace "unambiguous" with "effective" and still convey Bohr's intention. Thus, fruitfulness is a sign of objectivity in as much as an objective claim (unambiguously communicated) will point beyond itself to further productive claims. In science, fruitfulness comes in the way of further experimentation and theories. Similarly, productive dialogues are fruitful in pointing beyond themselves to further dialogue. All the time guided by what Gadamer calls die Sache--or the subject matter. (This will be treated in the section of "Reality and Truth" below).

Remarking on the fact that words are much richer than we can know, Bohr has the following insight,

> Our washing up is just like our language...We have dirty water and dirty dishcloths, and yet we manage to get the plates and glasses clean. In language, too, we have to work with unclear concepts and a form of logic whose scope is restricted in an unknown way, and yet we use it to bring some clarity into our understanding of nature.[131]

The point is given the "dirtiness" of language, the fact that concepts are not clear and univocal in meaning, communication, and with it knowledge, is something that (to paraphrase Whitehead) "should not be, and yet is."[132] We do convey meaning and give clarity to situations, despite the fact that our words are "dirty," laden with meaning, etc. That is

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[131] Quoted by Heisenberg in Physics and Beyond, p. 137.

[132] Whitehead makes the same remark about God.

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precisely because we formulate language out of a response to reality. One encounters the same situation with regard to observation. Despite the fact that observation is theory-laden, we are still observing nature herself.

Quite similarly, just as the dishwater is dirty, not as clean as we thought, so too is language. And nevertheless, they both get the job done. Nonetheless, the plates will not be as pristine as we might like. They will have something of the water on them. Likewise, our utterances will have a host of associations that each word brings with it--including the "infinity of the unsaid." And nevertheless, in both cases, we get the job done.

Not only did Bohr understand the philosophical enterprise dialogically, but perhaps most importantly he understood science itself in a dialogical way. In preparing for the Compton Lecture of 1957, Bohr wrote,

> ...but we have learned that our task is the development of human concepts, to find a way of speaking which is suited to bringing order into new experience and finally being able to put questions to nature in a manner in which we can get help with an answer.[133] (emphasis added)

In other words, if we ask the right sorts of questions, nature will be more forthcoming with a response. Such proper modes of questioning will be those that enable more questions to be asked--or--keep the dialogue going. There is an undeniable pragmatic element at work here that makes the future our gauge

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[133] Niels Bohr Archives MSS 1 cited in Honner, The Description of Nature.

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of success.

It is quite interesting that both Bohr and Heisenberg repeatedly claim that in scientific experimentation we are in contact not merely with nature as such, but with nature as subject to our mode of questioning. The questions will determine the kind of responses we get. That is why it was so essential that we learn to ask the right questions. For example, rather than asking what the true nature of light is--a question that nature seems to resist answering--we must instead learn to ask how light behaves under certain circumstances--and ultimately, how we can communicate these experiences to others. Asking the rights sorts of questions is tantamount to entering the dialogue in the right way. In that respect, it cannot be the case that "anything goes." There is a reality that guides our questions and determines what we can ask. Bohr's point is that if we are not asking the right sorts of questions, we will have no help with the answers. Gadamer often makes the very same point. For him, hermeneutics demands that we enter the dialogue in the right way. Each dialogue or interpretation is guided by what Gadamer calls die Sache--or the "subject matter." If we stray too far from the subject matter at hand, our dialogical efforts will be frustrated. It is in these circumstances that a dialogue might end. Similarly, in science, our "truer" theories will be those that allow us to question further.

In the view of both Bohr and later Heisenberg, quantum

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theory forcefully reminds us that natural science is made by man. It is not simply a symbolic representation of nature, but a part of the interplay between nature and man. Both Bohr and Heisenberg often quoted von Weizsäcker approvingly when he stated that "Nature is prior to man, but man is prior to natural science." Nature does exist independently of our ideas of it, but natural science is our attempt to create a work (in the form of a dialogue) that somehow allows nature and reality to shine through and reveal itself. Science gives us access to that reality. In that sense natural science is a work of man, a creation, and subject to the same interpretation as other works. Both Bohr and Heisenberg often described the nature of that work as a dialogue. Rosenfeld notes that one of Bohr's favorite expressions was that "our experiments are questions that we put to nature; and in our theories we try to state what we have learned from her in a language ensuring unambiguous and objective communication."[134] In characterizing scientific experiments as a dialogue with nature, there appears that same anticipation, frustration, and renewed anticipation that is characteristic of any questioning. (Incidentally, one sees this same thing at work in Popper's conjectural model.) Rather than following the linear model of induction, scientific thought as dialogue is closer to the kind of

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[134] Léon Rosenfeld, "Niels Bohr's Contribution to Epistemology" in Selected Papers of Léon Rosenfeld, p. 53.

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thinking exhibited by the hermeneutic circle--the give and take between whole and part. In fact, the experiment takes on the role of the "thou" of dialogue. We recall that for Gadamer understanding takes place when one enters into dialogue in such a way that he is open to the possible truth the "thou" has to say (whether the "thou" be another person, a text, or in this case, an experiment). In that respect, Gadamer emphasizes the Socratic docta ignorantia. Interestingly enough, a claim Bohr often made was "I did not look for things but found them," denoting an openness to possible experience and meaning. True understanding requires being prepared to amend your position or your initial interpretation if that is the way the dialogue goes. This is the dialogic nature not only of language, but of all experience. For Gadamer experience itself takes on the posture of dialogue. Insofar as we now perceive natural science in this way, the enterprise becomes hermeneutic. To make this claim is not to assert the meaningfulness of natural objects, as many opposed to a hermeneutic view of science maintain. Rather, to call the natural sciences hermeneutic is to accept the indispensability of language, its essential metaphoricity, the dialectic/dialogic nature of all understanding, and most importantly, to recognize the disclosive nature of truth. The point is that we as human thinkers use the same operations of thought and understanding

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regardless of the subject matter or field of study.[135] As Bohr himself suggested, why not draw upon the conclusions in one field of study for use in solving problems in another, possibly far removed discipline. This was part of his epistemological lesson and evidence of the holism at work in his thought. The key is, in promoting a position of holism, not to fall into a relativism that ends up with a Feyerabendian "anything goes." What we will see is that neither Bohr's thought nor Gadamerian hermeneutics will lead one to such a position.

Finally, in the 1960 essay entitled, "The Unity of Human Knowledge" Bohr notes,

> The aim of our argumentation is to emphasize that all experience, whether in science, philosophy, or art, which may be helpful to mankind, must be capable of being communicated by human means of expression, and it is on this basis that we shall approach the question of unity of knowledge.[136]

This requirement of communication is one that applies to all fields of inquiry and Bohr places it at the center of his claim to the "Unity of Knowledge." In that sense his thought is consistent with an ontological hermeneutics that claims understanding through dialogue as a description of our situation in the world. Communication through dialogue is, for Bohr as well, the Wesen of philosophy.

Interestingly, we will see (in the last section below)

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[135] This was likewise the claim at the center of thought of Emile Meyerson.

[136] Bohr, Vol. III, p. 14.

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that the common aim and goal of all understanding for Bohr will be the understanding of different cultures and promotion of human welfare. He will claim that promotion of human welfare through understanding of other cultures is the aim and goal of any science. It is in this final discussion that we will fully broach the question of the unity of sciences from the hermeneutic standpoint.

For now we now turn to a discussion of a specific problem regarding our language in quantum theory--namely, the breakdown of our classical concepts.

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(d) Problem of Causality and the Breakdown of language

Another problematic aspect of quantum theory involves the seeming breakdown of our classical concepts. We encounter situations on the quantum level where our language seems to be inadequate. Most striking, is the inapplicability of the concept of causality to the quantum situation.

To restate the problem, classical causality would demand the following: If at a given time one determines the precise initial position and velocity (or momentum) of a particle, then one can likewise give its position and velocity at a later time. In quantum theory, however, as a result of the measurement problem, and Heisenberg's uncertainty relations (cf. above), one cannot determine these initial conditions with any degree of precision, jeopardizing those future predictions. One must therefore conclude that causality does not apply in the quantum domain. While causality certainly remains one of the most fundamental of classical concepts, it seems to break down in quantum theory. In fact, language in general seems to break down.

For some physicists, this did not pose that grave a problem. As Pais points out, "physicists gladly pay the price of giving up causality for the tremendous gain of understanding atomic and molecular physics, and more, in terms

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of the new mechanics."[137] And yet, can we really be said to understand? Bohr will point out that unless we reflect on such limitations of our concepts, we cannot be said truly to understand. He remarks that

> We can no more hope to attain to a clear understanding in physics without facing the difficulties arising in the shaping of concepts and in the use of the medium of expression than we can in other fields of inquiry.[138]

A likely solution to such a breakdown of language and concepts would be to formulate new concepts that can accommodate the situation. But this was not an option open to Bohr. Despite the inability for classical physics to account for phenomena on the quantum level we do not discard it. Rather, we understand its limitations. What we will see is that Bohr's reaction to this seeming breakdown of language is quite consistent with more post-modern views of language that tend to use language in a much more evocative and poetic, rather than deterministic way. In other words, language should not be used to picture reality, but rather to draw images by means of metaphor.

Bohr points out that the source of the problem is that our language is rooted in certain classical assumptions--foremost of these assumptions is the strict partition between subject and object, as Bohr states,

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[137] Abraham Pais, Niels Bohr's Times, In Physics, Philosophy and Polity (New York: Oxford University Press, 1991), p. 64.

[138] Bohr, Vol. I, p. 15.

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> It was pointed out that a close connection exists between the failure of our forms of perception, which is founded on the impossibility of a strict separation of phenomena and means of observation, and the general limits of man's capacity to create concepts, which have their roots in our difference between subject and object.[139]

Our language is rooted in a pre-reflective naive life-world that takes certain things for granted, foremost of which is the subject object distinction. So the logical thing to do in this anomalous situation would be to formulate new concepts that are not rooted in the subject/object distinction and that can accommodate these novel situations--new concepts that do not depend on the things our classical concepts depend on. This was the option preferred by people like Schrödinger, and interestingly enough, early on by Heisenberg. But from the very start, Bohr was steadfast in his commitment to classical language. In a 1958 essay, stressing the simple logic of this demand of maintaining the classical language, Bohr asserts that,

> The decisive point is to recognize that the description of the experimental arrangement and the recording of observations must be given in plain language, suitably refined by the usual physical terminology. This is a simply logical demand, since by the word "experiment" we can only mean a procedure regarding which we are able to communicate to others what we have done and what we have learnt.[140]

This is a sentiment Bohr has often repeated throughout his writings. The very social nature of the experiment (and of science in general), and the dependence upon communicability

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[139] Bohr, Vol. I, p. 96.

[140] Bohr, Vol. III, p. 3.

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for objectivity demands that we describe our experiences in a language that others can relate to. His claim was that ultimately, all experiences must be translated into classical language--the language of our everyday life experiences. Objectivity depends on it. By redefining objectivity as "unambiguous communication" Bohr's point is that we need to formulate our descriptions in a publicly shared language. And that can be none other than our classical language. In defending Bohr's insistence on retaining the classical language, Léon Rosenfeld asserted the following:

> ...but ultimately, surely, whatever you do in order to communicate what you think or what you observe to other people, you must use a language which they are capable of understanding. You must put them in such a situation that they can repeat your own observations so as to understand what you mean.[141]

This insistence on everyday language will be at the center of the hermeneutic element in Bohr's thought and will make interpretation a sine qua non for understanding in natural science.

So rather than abandon our classical concepts we understand their limitations. By declaring that our concepts do in fact have limitations, Bohr is aware he is opposing himself to Kantian a priorism. While many philosophers have

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[141] Quoted in S. Körner, ed., Observation and Interpretation in the Philosophy of Physics, Proceedings of the Ninth Symposium of the Colston Research Society held in the University of Bristol April 1st - April 4th, 1957 (New York: Dover publications, Inc.), p. 53. Hereafter, S. Körner, "Symposium."

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tried to bring out the Kantian aspects of Bohr's thought[142], it is clear that on the issue of a priorism he is most anti-Kantian. We will now consider briefly Bohr's acquaintance with and relationship to Kant's thought below:

Bohr has a very curious relationship to Kant's thought. In fact, many will maintain that Bohr himself never read Kant. The physicist (and philosopher) Von Weizsäcker states in his The Unity of Nature that "Niels Bohr is the only physicist in our time who--as far as I know, without having been influenced by Kant[143]--proceeded from fundamental insights similar to Kant's."[144] Be that as it may, it is clear that in terms of a priorism, Bohr is decidedly un-Kantian. One can rightly say that Bohr had Kant in mind in the following remark:

> Both in relativity and in quantum theory we are concerned with new aspects of scientific analysis and synthesis and, in this connection, it is interesting to note that, even in the great epoch of critical philosophy in the former century, there was only question to what extent a priori arguments could be given for the adequacy of space-time coordination and causal connection of experience, but never question of rational generalizations or inherent limitations of such categories of human thinking.[145]

Thus, according to Bohr, Kant was not critical enough. There was on Kant's part never consideration of a possible

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[142] For instance Honner, Kaiser, Holton.

[143] There is, nevertheless, clear influence on Bohr by Harald Høffding, who is a neo-Kantian.

[144] C.F. von Weizsäcker, The Unity of Nature (New York: Farrar, Straus & Giroux, 1980) p. 342.

[145] Bohr, Vol. II, p. 65.

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experience where classical concepts (i.e., space, time, causality) would not apply. And Bohr is quick to point out that in quantum theory we do have such experiences.

Along similar lines, remarking on the limitations of Kant's thought, and the fact that the quantum situation has forced us to go beyond certain Kantian claims, Bohr wrote the following in a 1955 letter to Wolfgang Pauli:

> ...I may for a moment remind of the days of so-called "classical" physics and "critical" philosophy, when in the description of the course of events the role of the tools of observation was disregarded and space-time co-ordination and causality were considered a priori categories. It is true that before the epistemological aspects of the problem were so widely cleared up, a certain confusion was prevalent, but after a thorough lesson which we have received, the whole situation including that of classical mechanics appears in a new light.[146]

The situation is quite different now, according to Bohr. It is not the case that reality and nature have changed, but rather, our awareness of them has. As was mentioned earlier, Bohr emphasizes the fact that the quantum theory has revealed facts about nature and reality that were "hitherto unknown." These conditions have always existed, but now, thanks to Planck's "happy intuition" we can be aware of them. What Bohr seems to be advocating is an emergent epistemology that changes as our experiences change. Indeed that is part of the epistemological lesson he bids us to heed. In addition to always being mindful of the conditions under which information

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[146] Letter to W. Pauli 25 March 1955, NBA; quoted in Henry Folse, The Philosophy of Niels Bohr (New York: Elsevier Science Publishing Co, 1972), p. 216.

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is obtained (including the influence of the subject), we must now adopt a new attitude toward our concepts and our epistemology. The novel situation forces us to be more liberal with regard our concepts. As new situations are encountered, we will have to alter our epistemological claims to accommodate the novelties.--always bearing in mind, however, that ultimately, in order to communicate to others (secure objectivity) we must rely on our classical concepts. But, we now understand these concepts in a new light. They are necessary for communication, but not universal.

In a very recent article entitled "More Roots of Complementarity: Kantian aspects and influences," David Kaiser gives an extremely thorough, (but not always precise) treatment of the Kantian aspects of Bohr's thought. Kaiser attributes the rejection of a priorism to William James and Harald Høffding. He points out that one finds in both James and Høffding a separating out of elements of Kant's thought, both thinkers seeing fit to reject a priorism as unjustified and inadequate. Kaiser points out that "Høffding's own characterization of Kant repeatedly emphasized the limitation theme of Kant's philosophy, while ignoring or rejecting Kant's a priorism."[147] And it is precisely this emphasizing of limitations while rejecting of a priorism that we see in

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[147] David Kaiser, "More Roots of Complementarity: Kantian Aspects and Influences," Studies in the History of the Philosophy of Science, Vol. 23, No. 2, pp. 213-239, 1992, p. 233.

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Bohr's thought.

Harald Høffding devotes a substantial portion of his History of Modern Philosophy, to a treatment of Kant, (essentially doing for Kant what Copleston does for Aquinas). In this work Høffding criticizes Kant's quest to enumerate the number and kind of the a priori categories as a remnant of his early dogmatism.[148] As Høffding writes,

> For the analytic method employed by Kant cannot guarantee completeness; we can never be perfectly certain that all forms have been discovered. Neither can we feel sure that the forms we have discovered are the most fundamental. The forms are the constant element in experience, and from this constancy Kant argues that it must be the faculty of knowledge which is active. But this is, and will always remain, nothing more than an hypothesis.[149]

It seems as if Bohr seized on this shortcoming in Kant's thought (that he no doubt learned from Høffding) and saw it as an opportunity to have a more liberal attitude toward not only our concepts, but language in general. And interestingly enough, it was physical science that forced us to take seriously such limitations in Kant. In his late reflections on the philosophical aspects of quantum physics, Heisenberg remarks on this very same point. He notes that,

> ...what Kant had not foreseen was that these a priori concepts can be the conditions for science and at the same time can have only limited range of applicability.

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[148] See especially David Kaiser, "More Roots of Complementarity" regarding Høffding's treatment of Kant and its influence on Bohr's thought.

[149] Harold Høffding, History of Modern Philosophy, translated by B.E. Meyer, 2 vols. (London: Macmilllan, 1908), Vol. II, p. 51.

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> Modern physics has changed Kant's statement about the possibility of synthetic judgments a priori from a metaphysical one into practical one. The synthetic judgments a priori thereby have the character of a relative truth.[150]

While pointing out such limitations inherent in the Kantian system is by no means new to philosophy, what is novel is making the claim that we now had practical evidence of such limitations. One cannot apply the concept of causality to what is experienced at the quantum level because of a fact about nature. While that may only prove problematic for those more philosophically minded of physicists, (see Pais' statement above), what remains more profound on the part of Bohr is treating this problem as a model for putting forth a more liberal notion of language in general. Both reality and experience are oftentimes richer than language can convey. And yet, as we recall from the previous chapter, we are "suspended in language." Our understanding is limited to whatever language will allow us to convey. Rather than try to formulate a new language, we accept the limitations of the language we do have. And yet, those limitations seem to be less restrictive once we recognize that the true function of language is evocative and metaphoric. This will above all require that we abandon a picture theory of language. But before we consider these claims, we return briefly to the relationship between Bohr and Kant.

What Bohr's thought does share with Kant's is an emphasis

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[150] Werner Heisenberg, Physics and Philosophy, p. 90.

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on the transcendental.[151] Bohr is most concerned with elucidating the conditions for experience, the conditions for unambiguous communication, and, as we shall see, the conditions for understanding. This is something he likewise shares with Gadamer. We recall that in the Foreword to Truth and Method, Gadamer affirms that he shares with Kant this concern for the conditions of understanding--that which cannot but be the case. Gadamer recognizes that he is indeed asking a question, much the way Kant did, when he asks, "how is understanding possible? This is a question which precedes any action of understanding on the part of subjectivity."[152] We will see how Bohr's concerns increasingly reflect this emphasis on elucidating the conditions for understanding and determining what cannot but be the case.

Another Kantian theme that runs through Bohr's thought (something likewise gleaned from Høffding) is the imposition of limitations on what we can know. However, rather than attributing the limitations to the nature of human understanding (as Kant seems to do), Bohr will claim that limitations on what we can know are a function of nature or reality itself and the language we use to describe that reality. (This will be discussed at length in the next section on "Truth and Reality").

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[151] In The Description of Nature, John Honner characterizes Bohr as a "transcendental metaphysician" in the ranks of both Kant and Aristotle.

[152] Gadamer, Truth and Method p. xviii.

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In the article mentioned above, David Kaiser goes on to claim that Bohr rejects a priorism while accepting the phenomena-noumena distinction. I don't think one can make a case for Bohr's acceptance of the latter distinction. For Bohr it is clear there is no noumenal behind the phenomena. Rather, (as we shall see), Bohr would be closer to phenomenologists who place the noumenon in the phenomena, and have a more perspectival understanding of phenomena and reality.

To summarize, it is the case that on the quantum level the classical concepts, the very ones Kant had declared a priori necessary for all experience, seem to fail when it comes to the quantum theory. Since we have no choice but to utilize these concepts, we must rethink what we mean when we use them. As Ernan McMullin points out in his recent work entitled Construction and Constraint,

> Even causality seems threatened. The decay of a single radium atom is in principle unpredictable; not only can no current theory predict it, no future theory can either, if the implications of recent analyses of the consequences of Bell's Theorem are to be trusted. Does this mean it is uncaused? I think not, but it obviously forces us to reconsider what we mean by causality.[153]

By rethinking what our concepts mean, we will likewise be able to rethink the function of language in general. And what we will see is that the function of language is not to mirror reality. As we will see, Bohr's alternative to a picturing

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[153] Ernan McMullin, ed., Construction and Constraint: The Shaping of Scientific Rationality (Notre Dame: University of Notre Dame Press, 1988), p. 17.

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theory of language will have much in common with McMullin's more hermeneutic approach to understanding scientific language.

In fact this ability to test the range and scope of our fundamental concepts is, according to Bohr, the most essential contribution science can give to philosophy. By extending our experiences the way natural science does, we are given the chance continually to test the conceptual waters and become more critical as we do so. In a 1958 article entitled "Quantum Physics and Philosophy: Causality and Complementarity" Bohr notes that

> The significance of physical science for philosophy does not merely lie in the steady increase of our experience of inanimate matter, but above all in the opportunity of testing the foundation and scope of some of our most elementary concepts.[154]

Science offers us a chance to examine what it is we do when language does not perform as it should. According to Bohr what should happen is that we take a more liberal attitude, recognize the limitations of language, and most importantly, formulate a new conception of truth and reality. Interestingly enough, Bohr saw a curious precursor for this more liberal attitude toward our concepts in none other than Einstein. He notes that

> It was Einstein's elucidation of the limitation which the finite velocity of propagation of all force effects, including those of radiation, imposes upon the possibilities of observation, and therefore, upon the application of the space-time concepts, that first led us

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[154] Bohr, Vol. III, p. 1.

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> to a more liberal attitude toward these concepts, an attitude which found its most striking expression in the recognition of the relativity of the concept of simultaneity.[155]

Indeed, there are many moments in the history of physical science where we were forced to alter certain conceptual presuppositions. In fact Bohr equates the fact that we must forego deterministic description as a result of quantum theoretical description as being tantamount in profundity and effectiveness to the fact that (1) in classical mechanics we get a renunciation of the need for a cause for uniform motion, and (2) in relativity theory we are taught how arguments of invariance and equivalence must be treated as categories of rational explanation. In these circumstances as well we are given an epistemological lesson. For some odd reason, Bohr finds much more opposition to the present lesson than to those found in the past. Nevertheless, an analysis of the history of physical science provides us with a wealth of instances where "the exploration of ever wider fields of experience, in revealing unsuspected limitations of accustomed ideas, indicates new ways of restoring logical order."[156]

So what is the nature of this "more liberal attitude" toward our concepts? It is one that accepts the richness of language and draws on the resources of analogy and metaphor. In fact, Bohr is quick to point out that such a breakdown of

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[155] Bohr, Vol. I, p. 3.

[156] Bohr, Vol. II, p. 74.

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language only occurs as long as we demand visualization. The problems dissipate when we abandon the need for pictorial representation. In a letter to Høffding Bohr expresses the inadequacies of pictures in the following way,

> ...In general, however, and particularly in some new fields of investigation, one must remember the obvious or likely inadequacy of pictures: as long as the analogies show through strongly one can be content if their usefulness--or rather fruitfulness--in the area in which they are being used is beyond doubt...Here we find ourselves in the peculiar situation that we have obtained certain information about the structure of the atom which may surely be regarded as just as certain as any one of the facts in natural science. On the other hand, we meet with problems of such a profound kind that they seem to defy solution: it is my personal opinion that these difficulties are of such a nature that they hardly allow us to hope that we shall be able, within the world of the atom, to carry through a description in space and time that corresponds to our ordinary sensory images.[157]

It is this appeal to analogy for its usefulness and fruitfulness that bears a striking resemblance to the more hermeneutic approach to the philosophy of science especially as found in the writings of Ernan McMullin. And it is precisely this renunciation of demands for visualization and pictorial representation that usher in the notions of metaphor and analogy. As Heisenberg notes, "quantum theory thus provides us with a striking illustration of the fact that we can fully understand a connection though we can only speak of it in images and parables."[158] And in a letter to Born, Bohr notes that quantum experiments

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[157] Cited in Honner, The Description of Nature, p. 49.

[158] Physics and Beyond, p. 210.

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> preclude the possibility of a simple description of the physical occurrences by means of visualizable pictures...such pictures are of even more limited applicability than is ordinarily supposed. This is of course almost a purely negative assertion, but I feel that...one must have recourse to symbolic analogies to an even greater extent than hitherto. Just recently I have been racking my brains to dream up such analogies.[159]

It is the case in quantum theory that we cannot picture[160] events as we seem to be able to do on the macro level. Picturing remains subject to the application of classical concepts of space time and causality, and as we have seen, these classical concepts are inapplicable in quantum theory. While it may initially seem that such a loss of visualization is a further limitation on what we can know, Bohr's point is quite to the contrary. Bohr is quick to point out that this is by no means a hindrance to advance. He claims that

> The limit, which nature herself has thus imposed upon us, of the possibility of speaking about phenomena as existing objectively finds its expression, as far as we can judge, just in the formulation of quantum mechanics. However, this should not be regarded as a hindrance to further advance; we must only be prepared for the necessity of an ever extending abstraction from our customary demands for a directly visualizable description

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[159] Collected Works 5:311, in Honner, The Description of Nature.

[160] Bohr has a distinctive, oftentimes puzzling, use of the term "picture." For him picturing requires the kind of veridical correspondence one finds in a naive realism, and would preclude the possibility of emendation. This is in contradiction with Bohr's conception of science as an ongoing process, ever open to revision.

Bohr often uses "picture" in contrast with "image." The concepts of "picture" and "image" and their relationships to reality and truth do nonetheless remain problematic not only in the thought of Bohr, but in philosophy in general as well.

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of nature.[161]

In fact, departing from this customary demand for a "directly visualizable description of nature" is liberating according to Bohr. He often speaks of our "emancipation from the demand for visualization." In that respect, one no longer has to be committed to a definitive picture. This emancipation remains the surest safeguard against dogmatism. The liberation from visualization will yield freedom from foundationalism, correspondence, objectivism, picture theory--in essence, all things symptomatic of the Cartesian anxiety mentioned above. What it frees us from most of all, is a more deterministic conception of language that tries to give a final word on how the world really is. Instead, this more liberal attitude toward our language that Bohr calls for is one that accepts the richness of language and its essentially metaphoric nature.[162]

Being able to use language more abstractly is more conducive to a pluralistic conception of knowledge that declares that there is no final word. And as Bohr often emphasized, the quest for understanding reality is one that never ends. There is no final word. As Rosenfeld has pointed out regarding Bohr's emphasis on the open-endedness of theory

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[161] Bohr, Vol. II, p. 114-5.

[162] There are many similarities between this renunciation of pictorial demand and Rorty's thesis found especially in Philosophy and the Mirror of Nature that in describing the world, the function of our language is not to mirror how the world really is.

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and description,

> He vividly realized that our proud theories are but temporary resting places of the mind on the unending road to knowledge. Such resting places, however, there must be where we may taste the joys of knowledge, feel that we have reached a certain harmony between our mental picture of the world and our experience of it.[163]

And most importantly, we must be aware all the time that such a "picture" can always be altered. The point is our use of both words and images is circumstantial. Only when we are aware of the appropriate circumstances of their use can we be said to use the terms unambiguously.

This is consistent with the hermeneutic claim that understanding remains a perpetually unfinished task. As Gadamer has claimed "Bewusstsein is more Sein than bewusst, more Being than consciousness, and Being is never fully manifest."[164] In other words, at no point can we be said to be in full possession of the truth. No picture is complete. This will be most apparent in the claim that neither the wave nor particle description "pictures" light as it truly is. And only an appreciation of the metaphoric nature of language will provide for a true understanding of the openness of our task.

This rejection of a demand for direct visualization leads to a more metaphoric conception of scientific description and theory. We recall that Bohr has made the claim that our words

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[163] Léon Rosenfeld, "Niels Bohr's Contribution to Epistemology," p. 525.

[164] Hans-Georg Gadamer, Philosophical Hermeneutics, p. 38.

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are "dirty" with meaning and will therefore always mean more than we intend. Along similar lines, in his ground-breaking work Personal Knowledge, which set the scene for much of the hermeneutic philosophy of science that was to come, Michael Polanyi makes the following claim:

> Just as owing to the legitimately tacit character of all our knowledge, we remain ever unable to say all that we know, so also, in view of the tacit character of meaning, we can never quite know what is implied in what we say.[165]

Because of that, our words cannot directly picture reality "as it really is." Implicit meanings always get in the way. In addition, due to this more dynamic conception of reality itself, a reality that reveals itself to us only perspectivally, no one description can exhaust the possible different ways of describing any aspect of reality. This point will be emphasized in the discussion of "complementarity" below.

One can say that when something is visualized it is pictured, enframed, and essentially closed off. It is precisely this notion of visualization that Bohr is criticizing in his demand for renunciation. This is where a correspondence notion of truth would be most applicable. If we want to picture what nature really looks like, we are calling for a final word on it. We recall that this is precisely what Bohr was guarding against. Rather, we must

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[165] Michael Polanyi, Personal Knowledge (Chicago: University of Chicago press, 1958), p. 95.

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always be ready for alterations and surprises in our experiences. In that respect, analogy and metaphor are much more appropriate to scientific explanation than attempts at direct pictorial accounts.

And yet, this is by no means a limitation on what we can know. In fact Bohr makes the point that this is actually an advance in our understanding:

> The resignation as regards visualization and causality, to which we are thus forced in our description of atomic phenomena, might well be regarded as a frustration of the hopes which formed the starting-point of the atomic conceptions. Nevertheless, from the present standpoint of the atomic theory, we must consider this very renunciation as an essential advance in our understanding.[166]

What we now understand is the true function of language. Language is not deterministic, but rather evocative. At best we can draw images of what situations are like. Science will benefit by drawing on the resources of metaphor and analogy and being liberated from the constraints of a picture theory of language. This is an advance in as much as it opens up new possibilities of description that may lead to further advances.

Rosenfeld repeats this sentiment regarding the liberating effects of renunciation of pictorial demand when he states,

> The words 'renouncement'(sic) or 'resignation' often used in this context are ambiguous in their emotional connotation. Renouncement may be felt as privation or as liberation.[167]

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[166] Bohr, Vol. I, p. 115.

[167] S. Körner, "Symposium," p. 44.

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To declare it a liberation, as Bohr often did, would mean that somehow picturing was limiting. To picture, in that sense, is to try to effect a correspondence with reality. As we have seen, such correspondence is not possible given the influence of the subject in any situation. And yet we are liberated in being able to understand. What we understand is not only physical nature, but more importantly, we understand what it means to "understand." For Bohr, it becomes clear that to understand is not to have the last word on the true nature of something. Rather, it is to elucidate the conditions under which understanding takes place. It is to bring our experiences to order in a coherent and communicable way.

If we abandon the requirement for visualization, we are much freer to employ our concepts. Thus the use of language becomes less restrictive. One can use words without worrying about the precision and univocality of their meanings, which is to use them metaphorically and suggestively. One can now use words much more poetically. And yet, objectivity is not compromised since by unambiguous Bohr now means aware of the fact that we are not making final ontological claims about the world, but rather communicating what has been experienced in a coherent way. Our communication is ambiguous only insofar as we attempt such visualization. In fact, Bohr himself remarks on this possibility in the following exchange with Heisenberg. Heisenberg recalls his first encounter with Bohr with the following dialogue:

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> Bohr: We must be clear that, when it comes to atoms, language can be used only as in poetry. The poet, too, is not merely so concerned with describing facts as with creating images and establishing mental connections.
>
> Heisenberg: But in that case how are we ever to make progress? After all, physics is supposed to be an exact science.
>
> Heisenberg then added: "If the inner structure of the atom is as closed to descriptive accounts as you say, if we really lack a language for dealing with it, how can we hope to understand atoms."
>
> Bohr hesitated for a moment, and then said: "I think we may yet be able to do so. But in the process we may have to learn what the word "understanding" means."[168]

Again, understanding is not picturing something in an exact way. Nor is it strict identification; Rather it is imaging in a more abstract way, using the resources of metaphor in such a way that we can communicate to others what we have experienced and they too can imagine to themselves, in images that are familiar to them. Our better imagistic descriptions are those that will promote further discussion and experimentation, and most importantly, further theories. Our "truer" (if we can use the term) accounts are ones that will bear fruit in the future. But that is the point; the future

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[168] Werner Heisenberg, "Understanding in Modern Physics," in Physics and Beyond, p. 40.

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will tell. Just as it was only the future that could determine whether the Ptolemaic or Copernican description of the heavens was "truer" (the Copernican bearing the fruits of Kepler and Newton, etc.). There is in this respect a pragmatic element to Bohr's conception of what a better account will be.

The more significant point Bohr wants to make here is that when we have such failures on the part of language to effect some kind of picture, we must have recourse to a more symbolic use of language, one that employs analogy and metaphor. In that respect we may learn from poets and artists. And we take such recourse to analogy and metaphor regardless of the field of study. Quantum theory provides an example where we do so in natural science. Examples abound where we would do the same in any of the "human sciences." Likewise, Bohr is addressing the seeming problem of incommensurability between the classical and quantum theories with an appeal to metaphor. This is precisely what a more hermeneutic approach to the philosophy of science suggests and what we find especially in the work of Ernan McMullin.

In his seminal article entitled "A Case for Scientific Realism,"[169] Ernan McMullin asserts the strength and power of metaphor for science. McMullin makes the case for scientific realism in the face of seemingly overwhelming

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[169] in Jarrett Leplin, Scientific Realism (Berkeley: University of California Press, 1984).

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opposition, including the apparent victory for the anti-realists who side with Bohr in the debates with Einstein. Nevertheless, according to McMullin, the attempts by people like Rorty and van Fraassen to leave the extraordinary fertility of our scientific theories at the level of brute fact is unphilosophical. McMullin claims that "it makes a very great deal of difference to the explanatory power or goodness of a theory whether it can call on effective metaphors of hidden structures.[170] His point is that the resources of metaphor are essential to the work of science and that the construction and retention of metaphor must be seen as part of the aim of science. This is consistent with and can be seen as a direct outcome of Bohr's rejection of direct visualization. To Bohr visualization marked the final word, a closing off and commitment to a picture "as it really is." But if we have recourse to the use of metaphor, we are not concerned with whether or not we are picturing the world "as it really is" (as indeed we aren't in either the wave or particulate description of light). We can instead draw on analogy and be truer to the real function of language, which is not to picture anyway. (This will be returned to below in the discussion of complementarity).

This is not to be confused with an instrumentalist notion of theory. There theory assessment becomes impossible. On the instrumentalist view of science one cannot declare that

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[170] Ibid.

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any theory can be truer than any other. As Osiander, perhaps the consummate instrumentalist, urged Copernicus, we do not have access to reality. In contrast, the point of both Bohr and McMullin is that we do have access to reality. It is just not as direct as we would like. Rather that access is through language that must draw on imagery, metaphor, and analogy. As McMullin points out,

> The language of theoretical explanation is of a quite special sort. It is open-ended and ever capable of further development. It is metaphoric in the sense in which the poetry of the symbolists is metaphoric--not because it is imprecise, but rather because it has resources of suggestion that are the most immediate testimony of its ontological worth.[171]

Metaphor can likewise be used to combat incommensurability. It gives a new level at which theory comparison, assessment and translation becomes possible. As we shall see in examining Bohr's discussion of understanding other cultures, this is precisely what he had in mind. And it is his framework of complementarity that provides for a more liberal understanding of "truth" and paves the way for use of metaphor.

In his work Gadamer likewise emphasizes the essentially metaphoric nature of language. Since he also makes the claim that "Being that can be understood is language" we see how understanding must depend on metaphor. Borrowing from Heidegger, Gadamer wants to claim that all understanding "has

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[171] Ibid.

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the structure of something as something."[172] By metaphor Gadamer means the application of the familiar to the unfamiliar by way of language. This is precisely what is going on in the understanding of quantum theory when we apply the familiar, classical language to the novel, unfamiliar, non-classical quantum experiences. In his Languages of Art, Nelson Goodman describes metaphor as follows: "Metaphor, it seems, is a matter of teaching an old word new tricks--of applying an old label in a new way."[173] And further, "...briefly, a metaphor is an affair between a predicate with a past and an object that yields while protesting."[174] This is precisely what takes place in Bohr's use of metaphor. The novelty of the quantum situation, with its features of discontinuity and non-locality, protests the application of classical terms. But, through metaphor, the application can be made.

It is quite clear that this was the direction Bohr was heading in by abandoning the demand for visualization. The possibility of a single picture universally covering all aspects of observation has been abandoned. Strict visualization denotes closure, and by maintaining a more

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[172] Martin Heidegger, Being and Time, translated by John Macquarrie and Edward Robinson (New York: Harper and Row, 1962), p. 189.

[173] Nelson Goodman, Languages of Art, (Indianapolis: Hackett Publishing Co, 1976), p. 69.

[174] Ibid.

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dynamic conception of both language and reality, Bohr's philosophy must reject closure. Again, as he states time and time again, we must always be ready for changes and alterations in our understanding of reality.

Likewise, by emphasizing imagery, Bohr seems to be bridging the gap between science and art. Interestingly, Heisenberg describes Bohr in the following way:

> Bohr uses classical mechanics or quantum theory just as a painter uses his brushes and colors. Brushes do not determine the picture, and color is never the full reality, but if he keeps the picture before his mind's eye, the artist can use his brush to convey, however inadequately, his own mental picture to others.[175]

And yet, we do not fault the painter for being inexact. Rather we praise him for his power to evoke and inspire. This more imagistic use of language in describing the quantum situation replaces visualization. Language that is evocative is closer to language's true function; it is not to picture, but to image.[176] The kind of image Bohr emphasizes is the type that always allows for an alteration. It is in this vein that Bohr often compared himself to Picasso[177] and the way he and other cubist painters combined aspects of experience in unusual, unconventional ways. Similarly, Bohr claimed that the quantum situation is such that we can no longer combine

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[175] Werner Heisenberg, Physics and Beyond, p. 37.

[176] Again, the reader must keep in mind Bohr's contrast between "picture" and "image."

[177] Rosenfeld and Pais both claim that Bohr found "a kindred spirit in Picasso" and the way he tried to depict reality and experience.

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experiences in the usual fashion. The kind of picture that Bohr renounces is the one that attempts to mirror the way a realist painter might. In fact, later in Bohr's writings and discussions, he placed great emphasis on the use of both images and parables. Again, because of these limitations, we are forced to renounce the demands for visualization. We can no longer picture the quantum phenomena inasmuch as the novelties encountered defy pictorial description. Bohr will ultimately claim that the classical theory itself is merely an idealization. He states that

> This discovery (Planck's discovery of the quantum of action) revealed in atomic processes a feature of wholeness quite foreign to the mechanical conception of nature, and made it evident that the classical physical theories are idealization valid only in the description of phenomena in the analysis of which all actions are sufficiently large to permit the neglect of the quantum.[178]

The point is that even on the macro level, such breakdowns occur. In other words, while we may think that our observations in no way "disturb" the objects we are observing, and that we can therefore ignore the subjective element in any encounters as the classical definition of objectivity demands, the fact is that (at the macro level) the quantum of action is so minutely small with respect to the other numbers involved, that there is no appreciable disturbance or involvement. Naturally, as Eddington once remarked, "you won't hurt the moon by looking at it!" The involvement of the subject can be

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[178] Bohr, Vol. II, p. 71.

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ignored; but it takes place nonetheless. The subject involvement seems to take place "behind our backs." This is why Bohr was so insistent that this fact of nature, (the quantum of action and the traditional assumptions it calls into question), is a "hitherto unrevealed fact about nature." It is not a new situation that did not exist before. Rather, it just wasn't revealed. Now that it has been, Bohr's point is, there is no going back. We must, in any encounter, be mindful of the subject, recognize the limitations of our language, and most importantly, be prepared for new facts.

There is a curious similarity, an openness and liberalness that people like Bohr, and Meyerson, down to Bachelard and Foucault all share. They all bid us be ready for changes, shocks, ruptures, and surprises. And precisely how we deal with those changes, shocks and ruptures is very telling --and, according to Bohr, potentially useful for philosophy, as well as a variety of disciplines. Bohr comments that,

> Recognition of the analogy in the purely logical character of the problems which present themselves in so widely separated fields of human interest does in no way imply acceptance in atomic physics of any mysticism foreign to the spirit of science, but on the contrary it gives us an invitation to examine whether the straightforward solution of the unexpected paradoxes met with in the application of our simplest conceptions to atomic phenomena might not help us to clarify conceptual difficulties in other domains of experience.[179]

Further, it is this preparedness for unexpected paradoxes

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[179] Bohr, "Biology and Atomic Physics" (1937) in Bohr, Vol. II, p. 20.

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(breaks, ruptures, etc), that is, according to Bohr, one of the most widely ignored aspects of the natural sciences and what gives rise to misconceptions in scientific understanding. Bohr notes that "the feature which characterizes the so-called exact sciences is, in general, the attempt to attain to uniqueness by avoiding all reference to the perceiving subject." That is the traditional conception of the natural sciences, and by and large goes unquestioned. However, if we are more receptive to what Bohr calls the "appearance of new facts," one should indeed be prepared to revise our fundamental concepts in order to accommodate these new facts. As Bohr continues,

> In the natural science proper, however, there can be no question of a strictly self-contained field of application of the logical principles, since we must continually count on the appearance of new facts, the inclusion of which within the compass of our earlier experience may require a revision of our fundamental concepts."[180]

The emphasis is on extending our experiences and being open to the appearance of new facts. When we encounter a new situation, in order to understand our experience, we must organize the data and make our experiences coherent. It may be the case that these experiences are such that our language cannot accommodate them. And yet we cannot abandon this language since it is the language of everyday life. But, as we have seen, if we abandon the requirement of visualization, we are much freer to employ our concepts. Thus the use of

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[180] Bohr, Vol. II, p. 97.

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language becomes less strict. One can use words without worrying about the precision and univocality of their meanings. One can now use words more poetically.

Bohr himself commented on this more liberal, less constraining use of language when he stated the following:

> It is more difficult to write in one's own language; for there one knows precisely what the words mean. In a foreign language one doesn't know it quite so well and so can let the words mean just what one wants them to mean.[181]

What Bohr came to see was that accepting the fact that one would not be able to describe atomic theory in the usual way, would be liberating. In fact, it was seen as one of the last hurdles for truly understanding experience not only in quantum theory, but all experience in general. We will learn what it means to understand not only in quantum theory, but what it means to understand in general. To understand is to order and make coherent what one has experienced in such a way that it can be communicable to others. Most importantly, this must take place through a shared language. Once we realize this, we can defer to the hermeneuticist, i.e. Gadamer, to elucidate further what takes place when we understand, and how to bring about the most productive, fruitful, and effective of possible understandings and interpretations.

With that we move to a discussion of the kind of realism one encounters in Bohr's thought, as well as his conception of "truth."

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[181] Cited in Pais, Niels Bohr's Times, p. 120.

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(e) Realism and Truth

Many maintain that as a result of recent conclusions of Bell's theorem, Bohr has emerged as victor in the debates with Einstein. This victory, however Pyrrhic, is usually seen as deciding matters in favor of the anti-realist. What the following discussion will show is that rather than conceding to the anti-realist, the Copenhagen interpretation of quantum theory is more compatible with both a philosophical and a scientific realism--albeit a more modest one. In fact we will see how Bohr's thought in general depends on and is consistent with a realistic framework. What this more modest realism will require, however, is a new conception of "truth."

It has been hinted at in previous sections that Bohr's philosophy is consistent with a both philosophical realism and a realistic notion of the scientific enterprise. What type of realism, one may ask, could be compatible with a theoretical system that denies the autonomy of an object? And what kind of realism disallows the application of classical concepts? This section will treat the kind of realism operative in Bohr's thinking, as well as the notion of truth he puts forth. We will see that both bear striking resemblances to the kind of metaphoric-pragmatic realism one finds in modern hermeneutics, as well as to a disclosive, perspectival, pluralistic conception of truth.

The first step in elucidating the kind of realist

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framework we are talking about is to distance Bohr's thought from that philosophy which it is most often associated with--namely, positivism. In fact, the most common assumption is that since the Copenhagen interpretation insisted on only speaking about the behavior of things "under observation" that it was countenancing a positivism that disallows the validity of anything which is in principle outside experience. That was never the case with either Bohr's interpretation, or the thinking of most physicists involved in the Copenhagen school.[182] For Bohr, there was a reality independent of our experiences and observations. But unlike Kant, who places this reality out of our reach and realm of experience, Bohr makes the claim that this reality is revealing itself to us partially in each experimental arrangement or experience. We are in contact with an independently existing particle when we track the motion of an electron through a cloud chamber. But the full description of that particle requires that we include the entire experimental arrangement, including the subject and means of observation. Whether or not we are in touch with how the world "really is" is not as important to Bohr. This is not something we could prove anyway. Rather we should be more concerned with describing our experience of that reality rather than the reality itself[183].

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[182] Principally, Heisenberg, Pauli, Rosenfeld and Petersen.

[183] This distinction itself is problematic and remains the topic of much philosophical debate.

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We recall that physics is objective for Bohr if it provides unambiguous information. In other words, as he states,

> there is nothing that can be deemed subjective about marks on photographic plates and readings of spectrometers: all unambiguous information concerning atomic objects is derived from permanent marks...left on bodies which define the experimental conditions...the description of atomic phenomena has in these respects a perfectly objective character, in the sense that no explicit reference is made to any individual observer.[184]

In other words, no observer created those marks in the photographic plate--nor do they depend on someone observing them. The marks on the plate would be there whether or not anyone observed them. However, the description of the activity of the particles that makes use of the very notion "mark on a photographic plate" is a description of our encounter with the particles. As John Honner states, in The Description of Nature, "Bohr's notion of objectivity differs from the classical account, however, in that he stresses that our descriptions of nature are not descriptions of independent existing realities, but descriptions of our encounters with such realities."[185]

Ontology does yield to epistemology. But that does not mean in matters regarding ontology we must be silent. Rather our ontology is one that is never fully defined or disclosed. Each theory, like each encounter, reveals an "aspect of

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[184] Bohr, Vol.II, p. 68. and Vol. III, p. 3.

[185] John Honner, The Description of Nature, p. 146.

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reality". (This emphasis on describing our encounter with reality will be returned to below).

Quite analogously, along hermeneutic lines, one can say I do not write the words that appear on the pages of a text, nor does the anthropologist participate in the ritual he is attempting to describe. Nonetheless, my description of the text--or better stated, the meaning I derive from the text--is a result of my encounter with the text--just as the anthropologist's interpretation of the ritual is a result of his encounter with the people involved. The difference is, with the experimental arrangement there remains an independently existing state of objective possibilities that await subjective involvement. My encounter with light on the quantum level "forces nature's hand" so to speak, and prompts light to behave in a certain way. We will return to this below in the discussion of complementarity. For now we return to the discussion of positivism.

Bohr had a curious relationship with positivist philosophy. In fact, he is much more subtle in his criticisms of positivism than people like Heisenberg and Rosenfeld often are, and indeed much more forgiving. A claim that Bohr often made was that he could accept much of what positivism demanded, but could not abandon much of what they tried to prohibit. For example, in a somewhat apologetic tone Bohr makes the following claim:

> Now, all the positivists are trying to do is to provide the procedures of modern science with a philosophical

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> basis, or, if you like, a justification. They point out that the notion of the earlier philosophers lack the precision of scientific concepts, and they think that many of the questions posed and discussed by conventional philosophers have no meaning at all, that they are pseudo problems and as such best ignored. Positivist insistence on conceptual clarity is, of course, something I fully endorse, but their prohibition of any discussion of the wider issues, simply because we lack clear-cut enough concepts in this realm, does not seem very useful to me--this same ban would prevent our understanding of quantum theory.[186]

This was a sentiment Bohr often expressed. If conceptual clarity was conducive to unambiguous communication, then he was sympathetic to the positivist project. But not at the expense of the metaphysics and philosophical implications, which were a requisite part of understanding the quantum theory. Furthermore, as we will see below in our discussion of truth, Bohr will give a distinctive account of what "clarity" itself is and how it comes about, that is not quite consistent with what the positivists were calling for in their insistence on conceptual clarity. As Louis de Broglie has described him, Bohr was "the Rembrandt of contemporary physics with a predilection for obscure clarity."[187] (emphasis added)

In addition by declaring the need for the philosophical in order to understand quantum theory, Bohr chides the positivist for not realizing that the very nature of language

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[186] Quoted in Werner Heisenberg, Physics and Beyond, p. 208.

[187] Louis de Broglie, Perspectives in Physics, fn47, cited in Honner, The Description of Nature, p. 24.

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itself prohibits the attainment of the ideal they were trying to achieve. As we recall, our language is "dirty" and as such will always mean more than we intend it to mean. In addition, as Bohr has pointed out, our concepts are limited in their range of applicability. As a consequence we must renounce demands at visualization and pictorial representation and appeal to analogy and metaphor--something most inimical to the positivist quest for rigor. As Bohr states,

> The positivists are quite right when they stress the importance of linguistic accuracy and when they warn us that language may become meaningless once it eschews logical rigor. But perhaps they overlook the fact that in science we can at best try to approximate this ideal, but can never actually attain it. For the language with which we describe our experiments contains concepts whose scope we cannot define with precision.[188] (emphasis added)

Again, our attempts at logical rigor and clarity are frustrated by the very nature of language. In that respect, there will be many interpretations of any given situation, theory, or experiment given that we ultimately depend on ordinary language and communication for objectivity. In a similar vein Bohr notes that

> I do not object to positivism on the grounds that I would be less skeptical in this area (science), but rather because I am afraid that, in principle, things cannot be much better in science either. To put it in an exaggerated way: in religion we renounce the wish to give words an unequivocal meaning from the outset, while in science we start with the hope--or, if you like, the illusion--that one day it may be possible to do just

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[188] Quoted in Werner Heisenberg, "Discussions about Language" in Physics and Beyond, p. 135.

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that.[189]

The key term here is "illusion." We must realize that words defy univocal meanings. And yet, we are none the worse off because we are able to understand better to what extent we are "suspended in language."

Interestingly enough, Heisenberg was much more fervid in his criticisms of the positivist project. This is especially notable in light of his early alignment with them. In his 1925 paper, which many claim is the first statement on the new quantum situation, Heisenberg starts out by demanding that we limit our descriptions to what is in principle observable. It is there that he likewise suggests abandoning the classical concepts and touts the virtue and power of the new formalism he would develop. But by 1952 (and even earlier) Heisenberg had changed his position and continued to emphasize the limitations to the positivist project. He even goes so far as to admit the philosophical shortcomings of the new formalism as he states, "the paradoxes are merely hidden in the formalism--whether it be matrix mechanics or Schrödinger's wave mechanics."

In his later work Physics and Beyond, Heisenberg offers the following criticism of positivism,

> The positivists have a simple solution: the world must be divided into that which we can say clearly and the rest, which we had better pass over in silence. But can anyone conceive of a more pointless philosophy? If we omitted all that is unclear, we would probably be left

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[189] Ibid, p. 135.

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> with completely uninteresting and trivial tautologies.[190]

The point is strict clarity, correspondence and a picture theory of truth are not only pointless, but uninteresting. Given the essentially metaphoric nature of language, Heisenberg's point is that if we honored the positivists demands, we would be silent much more often than we would like to be.

Perhaps the most adamant of all Copenhagen physicists who denounced the positivist project was Léon Rosenfeld. In his writings Rosenfeld often spoke of the "curse of positivism," calling it a pernicious charge, oftentimes dismissing it with an emphatic "not true!" (One is here reminded of MacIntyre's dismissal tout court of relativism with his "go away!") In a panel discussion on the topic of "Observation and Interpretation in Science," with such luminaries as Feyerabend, Bohm, Polanyi, Vigier, Körner and many others, Rosenfeld, speaking for Bohr and the Copenhagen interpretation, defended his position against such charges. He asserted that

> No scientist would accept the extreme positivist conception that there is nothing more in statements about phenomena than the conceptual expression of relations between sensations; he would maintain that such statements refer primarily to real processes of the external world."[191]

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[190] Werner Heisenberg, Physics and Beyond, p. 213.

[191] Léon Rosenfeld, "Misunderstandings about the Foundations of Quantum Theory," in S. Körner, ed., "Symposium," p. 44.

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It is just a notion of reality we are unaccustomed to. Reality has now been revealed to be multi-faceted, and most importantly, contextual.

And Rosenfeld likewise points out that

> ...as far as quantum mechanics is concerned, I would say that it is impossible to understand it without assuming that there is an external world which is independent of what we think and which is the ultimate origin of all our ideas.[192]

Reality is revealing itself to us in each encounter, each experimental situation; but it will never be revealed in its totality. In that respect, one can speak of "aspects of reality" or "degrees of contact with reality". Continuing the discussion (panel discussion above) of what kind of realism is at work in the Copenhagen interpretation of quantum theory, U. Öptik offers the following suggestion. Comparing Newton's law of gravitation to Einstein's general theory of relativity, U. Öptik remarks,

> I would still like to be able to say that in a certain restricted sense Newton's theory is true, in spite of the fact that we need a <u>qualitatively</u> different theory to make it exact. If we insist on calling Newton's theory entirely false, then I think we are faced with a situation of never being able to trust any of our theories to give a true real description of reality.[193]

Öptik concludes with the assertion that Newton's theory revealed an "aspect of reality" and can be considered true to a degree. The point is we should amend what it is we mean when we declare a theory true. Reserving the term "truth" for

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[192] Panel discussion in Körner, ed., "Symposium," p. 54.

[193] <u>Ibid</u>, p. 112.

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the description or theory that describes the world "as it really is" once and for all would mean that we would never use the term. It is the case that even though we have surpassed Newton's law, there is still a sense in which it is true, given a certain "frame of reference."[194]

It is precisely this conception of reality that one finds in Bohr's writings--a reality that reveals itself in a variety of ways. Bohr often spoke of degrees of reality and different planes of objectivity that are somehow fused in understanding. (This will be discussed at greater length in the chapter on "Understanding of Cultures"). This is most consistent with the kind of truth and reality one finds in modern hermeneutics--one that is perspectival and defies complete disclosure. Once again we appeal to the thought of Ernan McMullin and his proposal of a more "metaphoric realism." McMullin stresses the point that calling a theory true is not closing the book on other possibilities. Instead he suggests that

> The realist would not use the term "true" to describe a good theory. He would suppose that the structures of the theory give some insight into the structures of the world. But he could not, in general, say how good the insight is. He has not independent access to the world,

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[194] There is a similarity here between the notion of "degrees of truth" and Nelson Goodman's "Ways of Worldmaking" whereby the one world can be composed in a variety of ways through the construction of different systems of interpretation or "frames of reference." Again, with the pragmatic element deciding "rightness" from "wrongness." See especially Nelson Goodman, Ways of Worldmaking (Indianapolis: Hackett Publishing Company, 1978).

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as the anti-realist constantly reminds him"[195]

For McMullin, as for Bohr, the emphasis will be on revealing structures of reality in such a way that we are pointed towards which direction to go in the future. As Joseph Rouse describes McMullin's thought,

> McMullin emphasizes the projective or horizontal character of science. Scientific theories are not put forward as final accounts of fully understood aspects of the world. They are essentially programmatic, indicating possible directions for exploration and serving as a resource for disclosing and assimilating new domains and new aspects of old ones. It is with this character in mind that McMullin stresses the metaphoric quality of theoretical language.[196]

Progress is no more than indicating in which direction to go. Bohr was sympathetic to this emphasis on fruitfulness and future direction. In a letter to Sommerfeld, Bohr complains that

> In the later years I myself have often felt very lonely as a scientist because I had the impression that my endeavors to develop the principles of the quantum theory systematically to the best of my ability were received with very little comprehension. For me it is not a matter of petty detail, but a serious attempt to reach such inner coherence that there could be a hope of obtaining a more secure foundation for further constructive work.[197]

What was misunderstood was the metaphoric realism at work in Bohr's thought. While most physicists (especially Einstein)

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[195] Ernan McMullin, "A Case for Scientific Realism," in J. Leplin, Scientific Realism, p. 36.

[196] Joseph Rouse, Knowledge and Power, (Ithaca: Cornell University Press, 1987), p. 148.

[197] Letter to Sommerfeld, cited in Honner, The Description of Nature, p. 71.

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were trying to establish the final word on physical reality, it was Bohr's intuition that one must stress the open-endendedness of science and therefore look for fertile stopping grounds rather than final theories. We recall that (as stated above), for Bohr our theories are mere "temporary resting places" for the ever active mind. Likewise, as Rouse continues,

> McMullin's realism does not commit us to saying we are already close to the final truth about some scientific issues. It says only that we have achieved a revealing insight into the realist disclosure if we pursue it.[198]

If this metaphoric realism is too antithetical to the more orthodox realist project, then we once again appeal to Bernstein and declare that we have gone beyond realism. In that respect, we would have to agree with someone like Arthur Fine when he points out that it is not clear what realism is supposed to add to such explanations other than a certain percussive ("really!") emphasis. And yet if we relax the requirements for realism, we can claim a theory to be "true" with more freedom, as Öptik suggests.

According to Bohr and the Copenhagen interpretation, we are indeed in contact with reality. But, as the quantum situation reminds us, we are altering it with every encounter. Just as for hermeneutics our understanding of a text transforms both us and the text, so too, our understanding of nature transforms both the scientist and nature itself. And

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[198] Joseph Rouse, Knowledge and Power, p. 149.

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perhaps most importantly natural science gives us knowledge about ourselves with respect to our role as knowers in the world and our relationship to nature. The point is not to describe reality "as it really is" but to describe our relationship to it. The revealing of the quantum of action and the explication of the measurement problem has indeed brought the structure of science closer to "reality" in that it has revealed our real relationship to the world: It is a relationship whereby we alter, affect, and modify the course of events in the world. In this light, Rosenfeld notes that

> the realization of the mutual limitations imposed upon the use of classical concepts by the conditions of observation has forcefully reminded us of our own position in the world, and of the function of science in relation to this position. We are not merely contemplating the world, but acting upon it and thereby modifying its course.[199]

Quantum theory stresses the more active role we play in understanding the world. This active role is not merely that of a Kantian organizing of our sensory manifold, but actually affecting the course of events in the world, and therefore affecting what we can know. As a result of the measurement problem and the epistemological lesson it contained, we accept that we play an active role in determining how the world appears to us.

Perhaps the clearest statement on Bohr's philosophical realism is his description of how we formulate our language.

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[199] Léon Rosenfeld, "Misunderstanding about the foundations of Quantum Theory," in S. Körner, ed., "Symposium," p. 43.

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According to Bohr, words are a result of the interplay between man and the world that he finds himself in dialogue with. The point is not merely to cope, as Rorty might say, but to cope in such a way that we are in contact with reality. And the only gauge we have for that contact is how fruitful our discussions and encounters are. Mere word games are not enough. The example of the poker game in the discussion of language above stresses this point. We recall that in order to play the game, the cards were essential; the game could not be played with mere words of persuasion and bluffing. Likewise, there must be something behind our words and behind our theories that we are elucidating and revealing. However, we must accept that it is never given to us in full disclosure.

Finally, regarding the rejection of positivism, Bohr recounts the following: He recalls attempting to explain the Copenhagen interpretation to a group of philosophers, primarily positivists, as follows:

> Some time ago there was a meeting of philosophers, most of them positivists, here in Copenhagen, during which members of the Vienna circle played a prominent part. I was asked to address them on the interpretation of quantum theory. After my lecture no one raised any objections or asked any embarrassing questions, but I must say this very fact proved a terrible disappointment to me. For those who are not shocked when they first come across quantum theory cannot possibly have understood it. Probably I spoke so badly that no one knew what I was talking about.[200]

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[200] Quoted in Werner Heisenberg, Physics and Beyond, p. 205-206.

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There are a few points to be made regarding the significance of this quotation. First of all, Bohr has often emphasized that the quantum situation has provided an opportunity to shake the foundations upon which our customary classical theories are based. The novelty of the situation forces us to be critical and bring into question what we otherwise take for granted. The positivist reaction is not receptive to the revolutionary aspect of quantum theory; this would require being open to the possibility of revision and alteration in one's assumptions and conceptual framework. As Gadamer would maintain, it requires putting one's position on the line. Any attempt at understanding the quantum theory would reveal the unorthodox claims being made. But since the positivists equate understanding with "predictive ability" there is no need to be "shocked" by the theory. In that sense, they have not understood the theory at all. As Pauli pointed out in response to Bohr's lament,

> ...The positivists have gathered that quantum mechanics describes atomic phenomena correctly, and so they have no cause for complaint. What else we have had to add--complementarity, interference of probabilities, uncertainty relations, separation of subject and object, etc.--strikes them as just embellishments, mere relapses into prescientific thought, bits of idle chatter that do not have to be taken seriously. Perhaps this attitude is logically defensible, but, if it is, I for one can no longer tell what we mean when we say we have understood nature.[201]

One cannot equate understanding and truth merely with predictive ability. As Heisenberg was quick to point out,

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[201] Ibid, p. 206.

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that would make the Ptolemaic system just as correct as the Copernican. But the proof is in the fecundity of the theory and the ability to point beyond itself. The point is that the Copernican system bore fruits that the Ptolemaic could not even approach. Only the future will tell.

Secondly, the positivists audience, in their denying attempts at understanding would naturally have no questions. This shows an unwillingness to enter dialogue with the theory and evinces no openness to the possibility of alteration in one's position.

Another realistic aspect of Bohr's thought is his insistence that the quantum situation is a brute fact about nature. There is no "quantum world." Rather there is a quantum description of the world. This interaction between subject and object does not merely take place at the quantum level. Even though at the macro level, the quantitative effects of the interaction between observational devices and observed systems may be neglected, that does not mean that, as Rosenfeld has noted, "the presence of these observational devices (on the macro level) is not just as essential as in quantum theory for the very definition of the physical concepts." This is rather an explicit statement of what has always existed--even though it was not always so clearly recognized. The interaction takes place (at the macro level) "behind our backs" so to speak. So while we may think we can attain the objectivity of the Enlightenment in the natural

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sciences because of the firmly drawn dividing line between subject and object, we must bear in mind that this is a mere idealization. The classical theory is an idealization that can be seemingly realized only because the quantum of action is small enough in comparison to the other numbers so as to make interaction negligible. But it takes place nonetheless. Once again, while we recognize that we will not hurt the moon by looking at it, we can still agree with Bohr that the observer in any situation should at least be aware of the active role he plays in any act of observation. This awareness, according to Bohr, will give us a new attitude toward certain fundamental assumptions about our knowledge of the world--especially regarding its objective status. And it was recognition of this fact that, according to Bohr, would enable us to understand better our situation as knowers in all fields of inquiry.

It is notable that the need for understanding was of primary concern for those in the Copenhagen school, especially Bohr. Bohr often denounced not only positivist claims at avoiding interpretation and understanding (as we saw above) but also attempts at reducing the theory to formalism. He maintained that ultimately even the formalism must be translated into every day plain language and was subject to interpretation and communication. The mere formalist interpretation ignored the most essential truth being revealed by the new quantum situation--recognition of our position in

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nature and the epistemological lesson.

To understand for Bohr was to organize and make coherent our experiences in such a way so as to make them communicable to others in plain everyday language. In order to do that one must translate into the familiar. We must go from the unfamiliar to the familiar by way of metaphor and analogy. And yet it is certainly not the case that any one interpretation is as good as any other. As Rosenfeld points out,

> New ideas are, of course, creations of the mind; but they are by no means free creations. They only arise as a response to the always recurring necessity of adjusting our mental picture of the world to our changing empirical knowledge of it. In this perspective, the interaction between observer and phenomena appears as an inherent part of the process and thereby is also susceptible to rational description. We simply cannot afford to ignore the fact that science is a human activity tied up with the whole process of organic adaptation of man's mind to the external world.[202]

The point is that we are not free to formulate ideas pell-mell. While we do draw on the richness of metaphor, we cannot equate truth with "a mobile army of metaphors" as Rorty, (borrowing from Nietzsche), would like. Nor do we each get to "tell our own story." Rather, the realism keeps us in tow. Neither hermeneutics nor the philosophy behind quantum theory allows us to be arbitrary. Reality does not mean whatever I take it to mean. The awareness of the hermeneutic circle and the dialogic nature of experience demand on the

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[202] Léon Rosenfeld, "Conflict Between Einstein and Bohr," in Selected Papers of Léon Rosenfeld, p. 521.

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contrary that we come into the circle "in the right way." By stressing the importance of communication and fruitfulness for pointing in new directions, Bohr was emphasizing this same point. And one can imagine that he would agree with Gadamer's assertion that eventually "time will eliminate the inessential."[203]

Finally, we turn to the conception of Truth at work in Bohr's thought. While there is no clear formulation as to what precisely Bohr means by "true," there are nonetheless two ways in which he discusses the notion of truth in his writings that prove illuminating for understanding his philosophy. The first involves a favorite saying of his that he often repeated when asked about the nature of truth. Most philosophers and physicists alike have pointed out that Bohr's favorite aphorism was the following from Schiller's poem "The Sentences of Confucius":

> Nur die Fülle führt zur Klarheit
>
> Und im Abgrund wohnt die Warheit
>
> Only fullness/richness leads to Clarity
>
> And Truth lies in the Abyss

Explaining the importance of these lines to his thought, Bohr notes the following:

> ...The full mind is alone in the clear, and truth dwells in the deeps. The full mind in our case, is not only an abundance of experience but also an abundance of concepts by means of which we can speak about our problems and about phenomena in general. Only by using a whole

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[203] This will be returned to below.

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> variety of concepts when discussing the strange relationship between the formal laws of quantum theory and the observed phenomena, by lighting this relationship up from all sides and bringing out its apparent contradictions, we can hope to effect that change in our thought processes which is a sine qua non of any true understanding of quantum theory.[204]

Clarity comes out of fullness and plurality, yielding a conception of reality and truth that is many-dimensional. Again, there is no one way of expressing truth, according to Bohr. It requires many different accounts and is always subject to a specific frame of reference. Only when we consider the context under which any claims (or descriptions) are made, will we understand the "degree of truth" we possess. This was at work in Bohr's harmonizing the classical and quantum descriptions. Both were necessary for an understanding of reality, and thus both expressed a degree of reality."

John Honner makes the following remarks regarding Bohr's praise of the above aphorism,

> Unlike the situation of earlier periods, clarity does not reside in simplification and reduction to a single, directly comprehensible model, but in the exhaustive overlay of different descriptions that incorporate apparently contradictory notions.[205]

This is a very explicit statement on the movement toward a more hermeneutic framework. Away from simplicity, reductivism, toward plurality, difference, and multiplicity.

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[204] Quoted in Werner Heisenberg, Physics and Beyond, p. 209.

[205] John Honner, The Description of Nature, p. 24.

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And placing truth in "the Abyss" indicates that truth will always be partially hidden from us. Whatever revealing we may get will be countered by a mutual concealment. We are never in possession of the full story. As Einstein often remarked, "Bohr was like someone perpetually groping for the truth, but never grasping it." Finally to grasp it would mean closure and deny the infinite task of understanding.

The other way in which Bohr discussed truth involved the recognition of what he referred to as "two kinds of truth." As Bohr explains it in his 1949 essay entitled "Discussion with Einstein,"

> In the institute in Copenhagen, where through those years a number of young physicists from various countries came together for discussion, we used, when in trouble, often to comfort ourselves with jokes, among them the old saying of the two kinds of truth. To the one kind belong statements so simple and clear that the opposite assertion obviously could not be defended. The other kind, the so-called "deep truths" are statements in which the opposite also contains deep truth.[206]

By the first kind of trivial truths Bohr intended things like tautological assertions where calling them "true" was redundant (see Fine above). However, the more profound sense of "true" is the one that does not denote the final word in as much as its contrary could very well be equally revealing. The deep truths were the ones that mattered. In science we are searching for those "deep truths" in our theories. The point according to Bohr is to be aware of the fact that there is a possibility that from a different frame of reference, the

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[206] Bohr, Vol. II, p. 66.

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opposite of any "deep truth" may likewise be true. In fact, in his essay entitled "My Father," Niels' son Hans Bohr maintains that this notion of the "two kinds of truth" was indispensable for understanding his father's thought.[207] Again, truth here is not in terms of correspondence or a picture theory of language, but rather a more pragmatic notion that is always subject to alteration. This is consistent with Bohr eschewing of pictorial representation and the rejection of the closure of a final theory. Most importantly, this conception of truth is parallel to the hermeneutic understanding of truth as aletheia. In his later works, Heidegger defines truth in terms of the Greek aletheia,[208] a revealing of what is hidden and concealed. Truth, for Heidegger, is an interplay between revealing and concealing and can never be fully disclosed. In that respect, no single "true" statement can claim truth to itself. There are as such "degrees of truth" (see above). The opposite of any true statement (or theory, or world view), may very well contain an aspect of the true. This is the conception of truth one finds in Gadamer as well. While Gadamer does remain a bit vague on the notion of truth[209] (the word "Truth" does not even

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[207] Hans Bohr, "My Father" in Rozental, Niels Bohr: The Man and His Works.

[208] See especially Heidegger's "The Question Concerning Technology" and "The Origin of The Work of Art."

[209] In fact, Bernstein points out that since Gadamer often emphasizes the disjunction rather than the conjunction in the title of his work, a better title would have been Truth

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appear in the index of Truth and Method), he clearly appropriates and defends the Heideggerian notion of aletheia. However elusive the conception of truth remains in the thought of both Bohr and Gadamer, this less traditional way in which it is discussed does nonetheless provide for a different attitude toward whatever claims to truth we do make and lends itself to a more dialectical way of thinking. We will see the importance of this more dialectical way of thinking when we consider Bohr's notion of complementarity below.

It seems that many of the physicists involved in the Copenhagen school adopted this notion of "deep truths" and referred to it in explaining the kind of realism quantum theory espouses. As Heisenberg has remarked,

> And so both our formulations contained a large grain of truth, and Paul (Dirac) and I could console ourselves with an oft-repeated dictum of Niels Bohr: the opposite of a correct statement is a false statement. But the opposite of a profound truth may well be another profound truth.[210]

Interestingly enough, one often finds in Heidegger this distinction between something that is "merely correct" and therefore trivial, versus that which is profoundly true, or revealing in some way. We will see in the next section how this notion of a "deep truth" became indispensable in paving the way for an understanding of complementarity.

We have shown that the kind of realism behind Bohr's

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or Method.

[210] Werner Heisenberg, Physics and Beyond, p. 102.

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thought is a metaphoric realism that brings into question the very usefulness of such notions as truth and reality. While we do not dismiss them altogether, we certainly dismiss the classical conceptions of reality and truth. They remain additional concepts that we have "moved beyond."

Regarding the assertion that we have "moved beyond" certain traditional labels and theoretical positions, we consider the following amusing suggestion by Léon Rosenfeld. As a frontispiece to his 1968 article entitled "The Method of Physics" Rosenfeld humorously paraphrases Mark Twain's preamble to The Adventures of Huckleberry Finn as follows:

> NOTICE
> (with apology to Mark Twain)
>
> Persons attempting to find materialism in this report will be prosecuted; persons attempting to find idealism in it will be banished; persons attempting to find positivism in it will be shot
>
> By Order of the Author
>
> (Cf. the preamble to The Adventures of Huckleberry Finn)[211]

With that suggestion we move to a discussion of the pearl of Bohr's thought: Complementarity.

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[211] Léon Rosenfeld, "The Method of Physics," in Selected Papers of Léon Rosenfeld, p. 614.

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(f) Complementarity

i. Complementarity in Physics

Finally, a discussion of what Bohr considered to be the heart and soul of the Copenhagen interpretation of quantum theory--namely, his notion of complementarity. Bohr first introduced the term "complementarity" in his 1927 Como lecture. He prefaced his remarks with the assertion that he wanted to describe "a certain general point of view...which (I) hope will be helpful in order to harmonize the apparently conflicting views taken by different scientists."

What Bohr hoped to harmonize initially were the opposing descriptions of classical and quantum physics. We recall that the classical description of reality, with its causality, continuity, and visualizability, was diametrically opposed to the quantum description, which in turn called for discontinuity, wholeness, and renunciation of visualizability. The notion of complementarity was introduced by Bohr as a way of describing the relationship between the two world pictures. Rather than merely opposing each other, the classical and quantum descriptions should be seen as complementing each other. And as such, both were necessary for a full description of reality. As Gerald Holton remarks,

> What Bohr had done in 1927, shortly after the Heisenberg-Schrödinger debates, was to develop a point of view which would allow him to accept both members (descriptions) as valid pictures of nature, accepting the continuity-discontinuity (or wave-particle) duality as an irreducible fact, instead of attempting to dissolve one

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> member of the pair in the other as he had essentially tried to do in the development of the correspondence principle.[212]

The more Bohr's theory developed, the more he saw complementarity as a vital part of explaining what would otherwise be considered insurmountable difficulties. Bohr would call complementarity "a new conceptual framework," one demanded by the quantum situation. He often stated that "the new situation forces us to adopt a new mode of description." This new framework of complementarity would provide us with a new way of understanding our classical concepts such that they can be useful precisely where they seem to break down--namely, on the quantum level. We recall that it was a fundamental requirement for Bohr that we retain use of our classical concepts and way of describing the world despite the apparent limitations, for it was in that way that we would secure objectivity (now redefined as unambiguous communication). Rather than having recourse to formulate a new language or appeal to an artificial language (or mere formalism) what complementarity enables us to do is revise our understanding of the language we already have and employ. As Heisenberg was wont to explain it, "if our words didn't fit, Bohr would make them fit." In that sense one can say that rather than "saving the phenomena" Bohr's concern was with "saving the concepts." And it was by employing this new framework of complementarity

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[212] Gerald Holton, "The Roots of Complementarity," p. 133.

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that he was able to do so.

In addition to harmonizing the classical and quantum descriptions, complementarity became more and more indispensable to Bohr for harmonizing apparent dichotomies within the quantum description itself (and, as we shall see, ultimately as a useful tool for all fields of study in general). Most important of these dichotomies in physics that complementarity allows us to understand was wave-particle dualism. We recall that the source of the conflicting points of view lay in determining the true nature of light. As a result of the new quantum theory, wave-particle duality was once again thrust into the limelight. As Bohr comments in the 1929 version of the Como paper ("The Quantum of Action and the Description of Nature"):

> The situation which we meet here is characterized by the fact that we are apparently forced to choose between two mutually contradictory conceptions of the propagation of light: one, the idea of light waves, the other, the corpuscular view of the theory of light quanta, each conception expressing fundamental aspects of our experience.[213]

Depending on the experimental situation, light will exhibit characteristics of either a wave phenomenon or a particle phenomenon--but never both at once. Bohr will maintain that both descriptions are <u>equally</u> important for a full elucidation of light--both are necessary, and yet they cannot both exist simultaneously. Evidence for the wave description and evidence for the particle description can only be found under

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[213] Bohr, <u>Vol. I</u>, p. 107.

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different (mutually exclusive) experimental conditions to be chosen by the observer. Thus not only can the different manifestations of light not co-exist logically, (by the very definitions of wave and particle), but they cannot co-exist practically. The opposing descriptions will be found only in what Bohr calls different "planes of focus" corresponding to "different planes of objectivity." (We will return to this notion of "planes of objectivity" below).

Bohr explains that

> Indeed, the spatial continuity of our picture of light propagation and the atomicity of the light effects are complementary aspects in the sense that they account for equally important features of the light phenomena which can never be brought into direct contradiction with one another, since their closer analysis in mechanical terms demand mutually exclusive experimental arrangements.[214]

And later in his essay entitled "Discussions with Einstein" he states that

> Consequently, evidence obtained under different experimental conditions cannot be comprehended with a single picture, but must be regarded as <u>complementary</u> in the sense that only the totality of the phenomena exhausts the possible information about the objects.[215]

The point Bohr is making is that we take as a brute fact that under differing experimental conditions, certain phenomena will exhibit different, seemingly incompatible and contradictory characteristics. Classical theory tells us that in such circumstances, one of the pictures must be wrong. Therefore we must make a choice as to which picture is more

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[214] Bohr, <u>Vol. II</u>, p. 5.

[215] Bohr, <u>Vol. II</u>, p. 40.

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correct. In so choosing we are attempting to attain the objective description of light. What complementarity allows us to do is maintain the usefulness and descriptive value of both pictures in our understanding of the object in question (we are here talking about the phenomenon of light, but the same applies to the behavior of sub-atomic particles in quantum experimentation). Both wave and particle descriptions can be utilized provided we accept the fact that neither is picturing light (or reality, as the case may be), as it really is, if by really we mean once and for all. In fact Bohr reminds us that

> we meet here in a new light the old truth that in our description of nature the purpose is not to disclose the real essence of the phenomena but only to track down, so far as it is possible, relations between the manifold aspects of our experience.[216]

The "new light" with which we encounter this old (Kantian) truth is one that now acknowledges the fact that through these "manifold aspects of our experience" we are in touch with reality; however this contact is partial, contextual, and will appear different under different experimental conditions. And most importantly, description of these appearances is subject to the resources of our everyday language.

Bohr makes the claim that complementarity is a sine qua non for objectivity. Since he has defined objectivity as unambiguous communication, we see that complementarity is required for unambiguous communication. Without the framework

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[216] Bohr, Vol. I, p. 18.

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of complementarity, our claims would remain ambiguous. In other words, without the framework of complementarity, we may be misled regarding the use of our concepts. Our description of a double slit experiment would be ambiguous according to Bohr, if we intended that description to be making the claim that light is a wave phenomenon. But again, complementarity reminds us that such descriptions are not definitive pictures of what light (in this case) really is. Complementarity allows us--in fact demands us--to recognize the provisional character of such descriptions. Our description of light as a wave in quantum theory declares that light behaves "like a wave under those circumstances." Such a claim is ambiguous only if considered classically--to be picturing what light is "really" like. As is often stated regarding the quantum situation, "the way things are requires complementary accounts of the way they seem."

This is what Bohr means by calling complementarity "the only possible objective description." In the now infamous interview given on the eve of his death, Bohr made the following lament to Thomas Kuhn:

> No man who is called a philosopher really understands what is meant by the complementary description: They did not see that it was an objective description, and that it was the only possible description.[217]

Without complementarity, our descriptions would remain ambiguous. Without the framework of complementarity, we would

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[217] Quoted in John Honner, The Description of Nature, p. 23.

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succumb to contradiction.

Interestingly, just as in hermeneutic theory one often finds that such a contexualization of experience and emphasis on perspective often brings charges of subjectivism and relativism, so too in quantum theory does such an emphasis on the conditions of observation seem to jeopardize objectivity. Bohr does admit that complementarity rehabilitates the subjective as he notes that

> In view of the influence of the mechanical conception of nature on philosophical thinking, it is understandable that one has sometimes seen in the notion of complementarity a reference to the subjective observer, incompatible with the objectivity of scientific description.[218]

However, as he is quick to point out, the objectivity it compromises is classical objectivity. For a description to be objective, according to classical theory, one must be able to distinguish sharply between the observer and object of observation. We have seen that this is not possible in the quantum domain. In fact, on the quantum, level it is precisely this reference to the subjective that ensures objectivity, as it alerts us to the conditions under which evidence is obtained. We recall that the very notion of a phenomenon for Bohr includes the subject (means of observation, experimental conditions, etc.). As Bohr remarks just a few pages later,

> Far from containing any arbitrary renunciation of customary physical explanation, the notion of

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[218] Bohr, Vol. II, p. 90-91.

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> complementarity refers directly to our positions as observers in a domain of experience where unambiguous application of concepts used in the description of phenomena depends essentially on the conditions of observation.[219]

Objectivity in the quantum domain is not monolithic. By emphasizing "planes of focus" and "planes of objectivity" as he does, Bohr is emphasizing the fact that objectivity is not reserved for <u>one</u> description. Objectivity is itself relative--and yet knowledge is not compromised. While it is the case that whether or not light behaves as a wave or a particle depends on the experimental arrangement and therefore does in some respect seem to be contingent upon a choice made by the observer, the fact remains that corresponding to either of those choices is a well-defined and perfectly objective set of possible predictions (objective here meaning classically objective). What the observer determines in his choice of experimental conditions is not the object itself--but rather, how it appears, or, which aspect is revealed.

In his work <u>Varieties of Realism</u>, Rom Harré describes these objective states or possibilities as "affordances." He claims that all we know about reality is that when prodded with a certain kind of apparatus, it can be "shaped" in a certain kind of way (particulate or wave). As he states,

> One could look on physical apparatus as devices for forcing the ur-stuff [or "glub" as he calls the basic reality of the universe] to display itself in a certain 'shape.' A piece of apparatus designed to bring out the particle aspects of subatomic phenomena could be thought

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[219] Bohr, <u>Vol. II</u>, p. 99.

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> of as 'squeezing' the glub into particles. That the glub can be so squeezed is an interesting fact about it, but all we can say is that it has that affordance. For what physical reasons it can be so squeezed we have and can have no idea."[220]

In that respect, nature as it appears is "half-artifact, half-objet trouvé."[221] (Interestingly, we will see in the next section how Clifford Geertz will describe the anthropological study in this very same fashion--as a "fictio" or making). In other words, as was previously stated, our observations seem to "force nature's hand" to take on one of its objectively possible guises. But nonetheless, it needs us to prompt it on.

This dependence on the subject or experimental arrangement is a reminder of the fact that the full object itself--in this case light--remains half-hidden. Remarking on this half-hidden nature of reality, Henry Folse points out that

> Nevertheless, although committed to the reality of atoms, Bohr was simultaneously aware that whatever the nature of the atomic domain may be, it was not capable of being visualized by classical models. Bohr's keen sensitivity to the half-hidden nature of the atomic realm was balanced by his exceptional feeling for the experimental situation which makes possible knowledge of this realm.[222]

The significance of this recognition of the "half-hidden" nature of reality for our purposes comes not in the fact that

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[220] Rom Harré, Varieties of Realism: A Rationale for The National Sciences (New York: Basil Blackwell, 1986), p. 306.

[221] Ibid.

[222] Henry J. Folse, The Philosophy of Niels Bohr, p. 230.

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this is how Bohr came to describe the sub-atomic world, but rather that he saw in these discoveries a lesson that one must apply to all fields of study. The lesson involves recognizing the fact that truth in all fields of inquiry is partial, perspectival, and somewhat elusive. Along with whatever is revealed there is a concomitant concealing. In that sense we must recognize the fact that any description is one among many. The subject matter at hand, whether it be something physical, such as light, or something far afield such as the meaning of a text or cultural practice, will never be fully revealed, fully articulated, or fully explicated. This is precisely the nature of truth that one finds in hermeneutics. Appropriating the conception of aletheia from Heidegger, Gadamer emphasizes the partiality of any event of truth, the fact that any revealing of truth or meaning brings along with it a degree of concealing. No one interpretation can fully exhaust the meaning of any event. As we mentioned above in the section on language, any utterance brings along with it the "circle of the unsaid." And likewise, as Gadamer often points out, "objectivity always arrives on the scene too late."

Again, for hermeneutics nothing is ever revealed completely, and all understanding is partial. Since understanding is an ongoing process that never ends, we are always only in possession of part of the story. That is part of the virtue of the hermeneutic circle where part and whole

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are mutually dependent. And complementarity can serve to reminds us of that fact. As Wheeler describes it,

> What we take to be contradictions are not contradictions, he (Bohr) tells us; they are complementary insights. Each gives us part of the story. Our picture of the truth is not complete without both.[223]

No single description, no one account, is complete. That is why in quantum theory we must abandon picturing if we associate picturing with finality and correspondence. In its place, we utilize images that are understood metaphorically.

Indeed for Bohr our picture of the truth is never complete. We recall that for Bohr our theories are merely temporary resting places. Our understanding of nature is an ongoing process that must always adjust itself to the appearance of new facts. And one of those adjustments we make is to expand our conceptual framework with complementarity, allowing seeming contradictions to be parts of the same story. It is in this way that objectivity is saved. Nevertheless, as we shall see, it is an objectivity that depends on a dialectical[224] way of thinking that acknowledges opposition, conflicts, tensions and refutations rather than avoiding or reducing them.

This was precisely the kind of thinking Bohr used not only to understand the novelty of the quantum situation, but most importantly for our purposes, understanding in general.

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[223] John Wheeler, "Niels Bohr, The Man," p. 72.

[224] What we mean here by "dialectical" will be discussed below.

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It was his claim that truth/reality is never fully disclosed--and it was the complementarity framework that made sense of that fact in nature. Bohr often pointed out that such complementary relations already existed in other fields of study. The novelty here was the fact that we now had physical evidence that we must adapt to a more dialectical way of thinking. We now have a cogent model for the kind of thinking he preferred, as Rosenfeld points out,

> (Bohr) often evoked the thinkers of the past who had intuitively recognized dialectical aspects of existence and endeavored to give them poetical or philosophical expression. Our only advantage over these great men, he would observe, is that in physics we have been presented with such a simple and clear case of complementarity that we are able to study it in detail and thus arrive at a precise formulation of a logical relationship of universal scope.[225]

We now see that Bohr embraced the dilemmas encountered in quantum theory precisely because they allowed us to push our language to its limits. Wave language and particle language are mutually exclusive--and yet they reveal aspects of the same object They seem to be incommensurable, and yet they both are necessary for an understanding of the quantum situation. The only way to avoid ambiguity and contradiction, according to Bohr, is to think dialectically.

This is precisely what a more hermeneutical way of thinking allows us to do. It provides a way of thinking that puts stress on the possibility that things might be other than

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[225] Léon Rosenfeld, "Niels Bohr's Contribution to Epistemology," in Selected Papers of Léon Rosenfeld, p. 533.

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we think. In viewing science as "dialogue with nature" as Bohr often claimed, scientific thought is subject to the dynamic of the dialogue--that same give and take, and openness to the nuances of the subject matter that is revealed as the dialogue unfolds. Just as the dialectic is open-ended, so too is a dialogue open-ended and without closure. As Rosenfeld describes the virtue of dialectical thinking in understanding quantum theory,

> What this prepares us for is a more dynamic conception of knowledge that recognizes that one cannot attempt to arrest this thought at any stage of its unceasing development without closing one's mind to the understanding of its further progress.[226]

This same recognition is at work in Gadamer's description of hermeneutics and the dialogic nature of understanding. And it is above all a dialectical way of thinking. We now turn to an examination of the kind of dialectical thinking Bohr embraces.

What does dialectical mean here? There are two senses of dialectical that apply to Bohr's thought. They are 1) the sustaining of opposition and 2) the more Hegelian sense that recognizes the movement of thought. What follows is a discussion of both and how they are apparent in Bohr's thought.

The first sense in which Bohr's thought can be deemed dialectical is the way that it exploits antitheses, whether it be classical versus quantum theoretic conceptions, or wave

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[226] Léon Rosenfeld, "Strife About Complementarity" in Selected Papers of Léon Rosenfeld, p. 465.

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versus particle descriptions, rather than reducing them. The purpose of the dialectic of complementarity is to provide a framework whereby both sides (or descriptions) can continue to subsist without reducing one to the other. In his essay on complementarity, Mara Beller remarks that

> It is Bohr's ability to acknowledge the contradictory parts of experience, without trying to reduce them to one another (as his brilliant mathematical colleagues--Dirac, Born, Heisenberg, and Schrödinger--preferred) that marks his philosophy of complementarity.[227]

It is in the spirit of this kind of dialectical thought that Bohr often invokes Eastern thinkers like Buddha and Lao Tze (as was previously mentioned).[228] He attributed to them a recognition of a harmony existing between opposition, rather than discord that leads to the reduction of one to the other. It was likewise in this spirit that Bohr defended complementarity against attempts by people like Schrödinger and the Russian physicists to eliminate the particle component of quantum description and limit the scope of quantum theory solely to the wave aspect. Even Einstein, for all of his boldness in revolutionizing our understanding of concepts like relativity and simultaneity, and despite the fact that he made

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[227] Mara Beller, "The Birth of Bohr's Complementarity: The Context of the Dialogues," Studies in the History of the Philosophy of Science, vol. 23 No. 1, p. 178.

[228] Bohr had a keen appreciation for Eastern thinkers and often lauded their ability to see harmony where others might see strife. In fact, upon being awarded the Danish Order of the Elephant in 1947, Bohr chose as his coat of arms an emblem of the symbol for the Yin-yang and the motto, "Contraria sunt Complementa." See especially S. Rozental, ed, Niels Bohr: His life and Work as Seen by His Friends and Colleagues.

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use of the quantum in his photoelectric theory[229], resisted this way of thinking that accepted both wave and particle descriptions. Bohr often commented on the fact that Einstein often alluded to the mysterious "Gespensterfelder", or "ghost-waves" that somehow guided the particles. It is in this respect that Bohr's esteemed colleagues are criticized for a lack of appreciation for dialectical thinking. In response to Einstein's constant pressing of Bohr for a concise definition of complementarity, Bohr often retorted, "Einstein did receive a definition. He just did not like the one he got."

Remarking on Bohr's way of thinking, Rosenfeld has pointed out that Bohr "keenly feels the insufficiency of any one-sided analytic procedure; the harmony of things is made up of the interplay of apparently conflicting aspects."[230] Again, the emphasis is on exploiting the tension in the dialectic and having that be the basis for harmony.

Many have attributed the difficulty of accepting complementarity to the fact that we are not trained to think in this more dialectical, anti-reductionist way. As Gerald Holton remarks,

Even those who in their professional work in physics have

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[229] In that respect, Pais calls Einstein "the godfather of complementarity." See especially Abraham Pais, 'Subtle is the Lord...': The Science and Life of Albert Einstein (Oxford: Oxford University Press, 1982).

[230] See especially Léon Rosenfeld, "Niels Bohr: An Essay Dedicated to Him on the Occasion of His Sixtieth Birthday, October 7, 1945," in Selected Papers of Léon Rosenfeld, pp. 313-326.

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> experienced the success of the complementarity point of view at first hand find it hard or uncongenial to transfer it to other areas of thought and action, as a fundamental thematic attitude, the habit of accepting basic dualities without straining for their mutual dissolution or reduction. Indeed we tend to be first reductionists, perhaps partly because our early intellectual heroes have been men in the tradition of Mach and Freud rather than Kierkegaard and James.[231]

Holton goes on to show that it is precisely this first sense of dialectic, which we are presently discussing, that one finds in the notion of the "qualitative dialectic" of Kierkegaard[232]--a sustaining of oppositions without reducing them.[233]

The second sense of dialectic that is apparent in Bohr's thought is the more Hegelian notion that acknowledges a progressive movement of thought. We recall that the most profound difficulty most opponents had with Bohr's interpretation was the fact that causal determinism is put

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[231] Gerald Holton, "Roots of Complementarity," p. 154.

[232] There is evidence that Bohr did read Kierkegaard, and spoke approvingly of his thought. Upon sending a copy of Kierkegaard's Stages of Life's Way to his brother Harald, Bohr noted that "I have had very much pleasure in reading it, I even think that it is one of the most delightful things I have ever read, although I do not fully agree with it." See Rozental, Niels Bohr, His Life and Works as seen by His Friends and Colleagues.

[233] Holton remarks that "Kierkegaard's stress on discontinuity between incompatibles, on the "leap" rather than the gradual transition, on the inclusion of the individual, and on inherent dichotomy was as 'nonclassical' in philosophy as the elements of the Copenhagen doctrine--quantum jumps, probabilistic causality, observer-dependent description, and duality--were to be in physics." There is much written about the putative influences on Bohr by both Kierkegaard and William James, with much still to be resolved. See especially, Holton, "Roots of Complementarity."

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into jeopardy. In fact Einstein often asserted that causality was the last thing a scientist should be willing to give up. In that respect, what stands in the way of accepting the Copenhagen interpretation is a belief in determinism. While Bohr never denies the prevalence of determinism on the macro level, he does point out that the danger lies in attempting to enforce determinism universally. The kind of dialectical thinking required to understand and accept complementarity is one that can recognize determinism as merely a moment whose limitations have been revealed. In his essay "Strife About Complementarity" Rosenfeld describes the dialectic of complementarity as follows:

> We are here witnessing with striking clarity the unfolding of a dialectical movement according to the typical scheme. The impossibility of integrating the quantum of action into the body of deterministic laws of classical physics corresponds to the phase of 'negation'; in fact as Engels observes, the dialectical negation consists in recognizing a limitation to the validity of some concept, in the present instance the concept of classical determinism.[234]

This is what Bohr meant by realizing the limitations of our concepts and rejecting the a priorism in Kant's thought (discussed in the previous section). We must realize that determinism is not a priori true. In fact there is the same compelling evidence for accepting probability as there was in the past for accepting determinism. Our experiences at the quantum level confirm the existence of probability and

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[234] Léon Rosenfeld, "Strife about Complementarity," in Selected Papers of Léon Rosenfeld, p. 471.

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uncertainty as facts about nature. What we must do according to Bohr is alter our conceptual framework to accommodate those facts. The problem only comes when determinism, which is, (in Rosenfeld's words) an empirical scientific extrapolation, becomes metaphysical dogma.

It is in this light that we consider Einstein's famous quip regarding the gambling proclivities of God, or "Der Alte" as he often referred to Him.[235] There are two responses to Einstein's concern on the part of Bohr that are discussed in the literature and bear mentioning. The first is in his own essay entitled "Discussion with Einstein." There Bohr declares the following:

> ...Einstein mockingly asked us whether we could really believe that the providential authorities took recourse to dice playing, ("...ob der liebe Gott würfelt") to which I replied by pointing at the great caution, already called for by ancient thinkers, in ascribing attributes to Providence in everyday language.[236]

And Heisenberg often pointed out that Bohr's most frequent response was "don't tell God what to do."[237]

In that respect, Einstein can be seen to represent the more objectivist thinker in the dilemma of objectivism versus relativism described by Richard Bernstein (see chapter 1 above). As Bernstein describes him

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[235] Interestingly, Pais points out that Einstein used the appellation "Der Alte" to refer both to God and to Freud. See 'Subtle is the Lord...'.

[236] "Discussions with Einstein" in Vol II, p. 47.

[237] See especially Physics and Beyond and Physics and Philosophy.

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> At the heart of the objectivist's vision, and what makes sense of his passion, is the belief that there are or must be some fixed, permanent constraints to which we can appeal and which are secure and stable.[238]

For Einstein this was determinism. And yet, as we have seen, this limitation of determinism does not mean we must abandon objectivity. Rather, we are maintaining objectivity in the face of probability--in the way of the uncertainty relations that are a fact about nature.

The key for Bernstein, and indeed for hermeneutics, in the rejection of classical objectivism is not to fall into the alternative of relativism. The relativist, on the other hand, claims that there are no such basic constraints except those that we invent or temporarily accept. Rather, Bernstein's point is that hermeneutics contributes to the realization that we have gone beyond the either/or of objectivism and relativism. "Objectivism versus Relativism" is the general heading for the contrasts of rationality versus irrationality, objectivity versus subjectivity, and realism versus anti-realism, etc. The present claim is that the framework of complementarity and Bohr's thought in general are likewise indicative of the realization that we have gone beyond these categories. Any claim to objectivity is circumstantial, and in order to communicate unambiguously regarding such a claim, we must be aware of the circumstances involved.

Just as hermeneutics shows that the rejection of

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[238] Richard Bernstein, Beyond Objectivism and Relativism, p. 18.

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objectivism does not lead to relativism, and that the rejection of classical realism does not lead to anti-realism (we saw the alternative of a metaphoric realism above), likewise Bohr's framework of complementarity shows how a rejection of classical objectivity does not lead to a subjectivism, or "arbitrariness" as he refers to it. Rather, complementarity provides for objectivity that is relative to the "plane of focus." Thus the limitation on determinism redefines what we mean by "objective description."

Furthermore, Bernstein likewise points out that it is this same resistance to dialectical thinking that traps us in the above dichotomy. It is in this respect that he defines "Cartesian Anxiety" as the search for a "foundation" or Archimedean point upon which we can ground our knowledge. This Cartesian either/or, according to Bernstein, declares that "either there is a fixed foundation for our knowledge, or we cannot escape the forces that envelop us with madness, with intellectual and moral chaos."[239] Applied to the quantum situation, the either/or involved would be either we maintain the fixed foundation of determinism for our objective description of the world, or we cannot claim any objective knowledge. It was regarding this choice that Einstein and others claimed quantum theory to be incomplete. A complete, objective account must be deterministic, according to Einstein. What Bohr attempts to show is that one can lay

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[239] Ibid.

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claim to objectivity despite the element of probability. The feature of probability is an objective fact about nature. In that sense we have gone beyond classical objectivity.

Nevertheless, it was Einstein's view that without the foundation of determinism and causality, what we were left with was intellectual chaos. As he often noted of quantum theory, "one really ought to be ashamed of its success."[240] Even after admitting that Bohr's quantum theory was "...logically possible without contradiction..," Einstein nonetheless maintain to the end, "...but it is so very contrary to my scientific spirit that I cannot forego the search for a more complete conception."[241]

However, as Bohr and Rosenfeld never tired of pointing out, the Copenhagen interpretation of quantum theory is complete. The assertion regarding the incompleteness of quantum theory rests on the misconception that either our scientific theories reveal deterministic information or they are incomplete. Indeed, in order to accept the Copenhagen interpretation of quantum theory, this remains another dichotomy we must get "beyond."

Determinism does not apply at the quantum level. It is only while we cleave to the notion of determinism and allow it to be a metaphysical tether, that the Copenhagen

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[240] Letter to Born, cited in John Honner, The Description of Nature, p. 113.

[241] John Honner, The Description of Nature, p. 132.

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interpretation appears incomplete. The probability inherent in the uncertainty relations is objective, a fact about the nature of such processes. Again, recent advances regarding Bell's theorem notwithstanding, the point is that the quantum of action is an objective fact about nature and as such must be accommodated conceptually. If that means abandoning determinism as a requirement for objectivity then so be it, according to Bohr. Again, we are forced to rethink what we mean by objectivity. The value for philosophy in this rethinking is that we no longer need to be constrained by a specific (classical) notion of objectivity that by and large has been shown to be unattainable. If by objective we mean free from subjective influence and deterministic, both philosophy and now physics has shown us that this is not possible.[242]

Much current philosophy of science has shown that we have nothing more than a nostalgic commitment to classical realism

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[242] An adequate treatment of charges of incompleteness including discussions of Einstein and the EPR paper, Bohm's hidden variable theory, and Bell's theorem would require a separate study. Nevertheless, it is interesting to note that many Copenhagen physicists were quick to point out that any theory can be shown to be incomplete and that declaring that there are "hidden variables" is tantamount to "adding epicycles." (See especially, S. Körner ed., Observation and Interpretation in the Philosophy of Physics, Panel Discussion.)

As for Bohr, in response to Bohm's postulation of hidden variables, he gave the following retort: "We may hope that it will later turn out that some time 2x2=5 for this would be of great advantage to our finances." (quoted by Heisenberg in Physics and Beyond) In other words, we cannot change certain facts just because it would satisfy certain needs and desires we might have.

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and determinism. In fact (to borrow from Kant) there does seem to be a felt need to postulate classical realism, determinism and objectivity as ideals or values. However, as Larry Laudan has claimed, such beliefs, especially that of realism, remain at the level of wish-fulfillment.[243] Nevertheless, we are free to be fideists regarding our commitments to realism and truth, so long as we realize that might be all we have to go on.

Along similar lines, in defending the Copenhagen interpretation, C.G. Darwin points out the following:

> ...there are some who still deny the validity of Bohr's principle, and still hanker after something like the old determinism. To his dying day Einstein was one of these, and there are many others. If they can succeed they will certainly make it easier for us all to understand intuitively the basic laws of nature, but I can only record my own opinion, that I do not see why nature should have accommodated itself to this human weakness.[244]

It is precisely being open to the possibility of such frustrations that Bohr claims is required in understanding the new quantum theory.

Bohr himself may have anticipated the problem with complementarity given that the term was one that physicists and philosophers alike were unfamiliar with. In fact at one point Bohr considered using the term "reciprocal" instead of

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[243] See especially Laudan's Progress and Its Problems, and "Confutation of Convergent Realism" in Leplin, Scientific Realism.

[244] C.G. Darwin, "Observation and Interpretation" in S. Körner, ed., "Symposium," p. 218.

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"complementary" but preferred the latter term precisely because of its strangeness. Bohr felt that his coining the term complementarity was essential in so far as the term was relatively new and as such did not have many of the associations a more widely used term might have. He points out that

> The purpose of such a technical term as complementarity is to avoid, so far as possible, a repetition of the general argument as well as constantly to remind us of the difficulties which, as already mentioned, arise from the fact that all our ordinary verbal expressions bear the stamp of our customary forms of perception, from the point of view of which the existence of the quantum of action is an irrationality.[245]

And in his unpublished notes, Bohr remarks that

> The idea of using a word like "complementarity" and its possible uses is namely that it is a new artificial word, a word which cannot call upon any ideas about situations....[246]

The point is that complementarity is a term that is not as "dirty" as the rest of our language (see the section on "Language" above). It is a word that has not yet gained currency and therefore will not evoke all kinds of meanings. He likewise states that

> In the last resort an artificial word like "complementarity" which does not belong to our daily concepts serves only briefly to remind us of the epistemological situation here encountered, which at least in physics is of an entirely novel character.[247]

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[245] Bohr, Vol. I, p. 19.

[246] Niels Bohr Archives, cited in John Honner, The Description of Nature.

[247] Bohr, Vol. III, p. 7.

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And yet, is complementarity such a new and artificial term for Bohr? No discussion of Bohr's thought would be complete without a discussion of possible philosophical influences.

Much has been written about the conceptual and philosophical sources of Bohr's notion of complementarity. Whatever these sources are, they all seem to point back to the influence upon Bohr of Harald Høffding. There is not doubt that whatever philosophical training Bohr had was due to his association with Høffding. While at the University of Copenhagen Bohr studied philosophy with Høffding and kept in close contact with him throughout his career. And there is no question of the mutual respect the men had for each other.[248]

There are two philosophers whose thought contains elements which bear striking resemblances to aspects of Bohr's theory--and both these philosophers are given special attention by Høffding. They are William James and Søren Kierkegaard. Kierkegaard's conception of "qualitative dialectic" was mentioned above (and indeed provides a point of departure for an extensive study). What follows is a brief consideration of the possible influence upon Bohr by the

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[248] Høffding speaks highly of Bohr often in his correspondences with Emile Meyerson. And it is often noted that one of the portraits which hung prominently in Bohr's residence was of Høffding himself. (see especially Ruth Moore, Niels Bohr: The Man, His Science, and The World The Changed (New York: Alfred A. Knopf, 1966)).

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thought of William James.

Bohr himself has mentioned the influence of James on his own thought. In fact in the above mentioned interview with Thomas Kuhn Bohr makes the following remark:

> William James is really wonderful in the way he makes it clear--I think I read the book, or a paragraph, called..."The stream of Thoughts," where he in a most clear manner shows that it is quite impossible to analyze things in terms of--I don't know what to call it, not atoms, I mean simply, if you have some things...they are so connected that if you try to separate them from each other, it just has nothing to do with the actual situation....[249]

Bohr then notes that he read James' work Principles of Psychology around 1905, sufficiently early enough for it to have significant influence on his thought. While the moment of Bohr's initial acquaintance with James' work remains a topic of dispute,[250] there is no question of the similarities in their thought. Most notable is the use by James of the very same term we are discussing--namely, "complementarity."

The chapter Bohr refers to in the quotation above, while evincing the same sort of holism Bohr describes, is probably not as important as what occurs just before it in the text.

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[249] Quoted in John Honner, The Description of Nature, p. 18.

[250] Whether or not Bohr actually read James' work when he claimed he did, or much later (1932) as Rosenfeld claims, is a much disputed topic of debate in the literature, as is the precise amount of influence Høffding actually had on the development of Bohr's thought. For instance, Farvoldt denies any substantial influence on the part of Høffding, while Honner, Holton, and Beller claim otherwise.

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Just prior to the chapter that Bohr refers to above is a section titled "Unconsciousness in Hysterics." There James comments on primary (normal) and secondary consciousness in hysterics. He uses the term "complementarity" to describe the levels or kinds of consciousness schizophrenics experience. James writes that

> It must be admitted, therefore, that in certain persons, at least, the total possible consciousness may be split into parts which co-exist but mutually ignore each other, and share the objects of knowledge between them. More remarkable still, they are complementary. Give an object to one of the consciousnesses, and by that fact you remove it from the other or others. Barring a certain common fund of information, like the command of language, etc., what the upper self knows the under self is ignorant of, and vice versa.[251]

We can compare this remark to the following assertion by Bohr: Remarking on the use of complementarity in both psychology and physics he states that

> In such an analogy, [comparison between conscious experiences and physical observations], the impossibility of providing an unambiguous content to the idea of subconsciousness corresponds to the impossibility of pictorial interpretation of the quantum-mechanical formalism. Incidentally, psychoanalytic treatment of neuroses may be said to restore the balance in the content of the memory of the patient by bringing him new conscious experience, rather than by helping him to fathom the abysses of his subconsciousness.[252]

These different levels of consciousness are seen as complementary. Bohr often pointed out similarities between

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[251] William James, The Principles of Psychology (New York: Dover Publications, 1950), p. 205. For a discussion see especially Gerald Holton, "The Roots of Complementarity."

[252] Niels Bohr, "Unity of Knowledge" in Bohr Vol. II, p. 77.

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such levels of consciousness and the "planes of objectivity" discussed above.

Mara Beller points out that one finds the same emphasis on complementary notions in the thought of Høffding. He notes that

> Høffding emphasized the dialectical relation of whole and parts, continuity and discontinuity, rationality and irrationality. He treated knowledge as a set of partial views, when in different situations different sets of symbols are applicable, emphasizing the fluidity and incompleteness of all knowledge.[253]

Interestingly enough, Høffding was in intimate contact with James during the time that Bohr claims to have read the latter's work. Holton tells us that "at about the time Bohr took his philosophy course (with Høffding), Høffding used the occasion of the St. Louis meeting of 1904 to visit James in the United States. James, in turn, supplied an appreciative preface for the English translation (of 1905) of Høffding's Problems of Philosophy...And in the same year of Høffding's visit to James, Høffding expressed in his Moderne Philosophen his admiration for James' work, to whom the concluding chapter is devoted, with such comments as 'James belongs to the most outstanding contemporary thinkers....The most important of his writings is The Principles of Psychology.'"[254]

Whatever the order of discovery was for Bohr, the fact

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[253] Mara Beller, "The Birth of Bohr's Complementarity," p. 179.

[254] Gerald Holton, "The Roots of Complementarity," p. 144.

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that he intended the analogies to be brought out emphasizes both the holism at work in his thought and the willingness to draw on philosophical discussions for his interpretation of quantum physics. Indeed, he intended the influence between science and philosophy to be reciprocal. Just as we are reminded of situations in other fields of study which bear a striking resemblance to the quantum situation, so too should we apply the lessons gleaned from quantum theory to other fields of study. Not least of which, as we shall see, is the application of complementarity to the understanding of other cultures.

Regarding the importance of dialectical thinking in understanding Bohr's thought, certainly we do not mean to happily dismiss resistance to complementarity as a lack of appreciation for dialectical thinking. Indeed one must imagine there were plenty of Hegelians around when Bohr made his infamous complaint to Thomas Kuhn (see above). Rather the point has been to bring to light the kind of thinking Bohr employed and to show how similar it is to the more hermeneutical approach. Indeed, there still remains much puzzlement and debate regarding complementarity today. In fact Abner Shimony has remarked "I must confess that after 25 years of attentive--and even reverent--reading of Bohr, I have not found a consistent and comprehensive framework for the

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interpretation of quantum mechanics."[255]

There have been many accounts as to why Bohr felt dissatisfied with most accounts of complementarity as well as why complementarity continues to be a topic of much puzzlement and debate. Even those thinkers more sympathetic to the Copenhagen interpretation and Bohr's thought had difficulty with the complementary description. In his article, on "The Birth of Bohr's Complementarity" Mara Beller tells us that

> M. Jammer, commenting on the extreme difficulty of comprehending Bohr's complementary principle, described von Weizsäcker's extensive effort to elucidate the original meaning of complementarity. However, when von Weizsäcker asked Bohr "whether his interpretation accurately presents what Bohr had in mind, Bohr gave him a definitely negative answer."[256]

Thus Bohr's lament to Kuhn seems to extend to physicists as well.[257] And the notion of complementarity still remains

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[255] Abner Shimony, "Review of Folse's The Philosophy of Niels Bohr in Physics Today 38, 1985, 10, 109

[256] Mara Beller, "The Birth of Bohr's Complementarity," p. 148; see also Max Jammer: The Philosophy of Quantum Mechanics (New York: Wiley, 1974).

[257] In a wonderful illustration of the kind of thinking required for an appreciation of complementarity Rosenfeld recounts the following conversation with the eminent physicists Yukawa, discoverer of Meson theory:

> "When I was staying at Yukawa's Institute in Kyoto I had occasion to discuss Bohr's ideas with the great Japanese physicist. I asked Yukawa whether the Japanese physicists had experienced the same difficulties as their Western colleagues in assimilating the idea of complementarity and in adapting themselves to it. He answered 'No, Bohr's argument has always appeared quite evident to us' and, as I expressed surprise he added with his aristocratic smile, 'You see, we in Japan have not been corrupted by Aristotle.'"

in Rosenfeld, "Bohr's Contribution to Epistemology."

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puzzling today. As late as 1992, Beller has noted that

> Bohr's complementarity principle...remains a challenge and a puzzle. In the history of scientific thought it is hard to find another central contribution about which the opinions continue to differ so sharply more than half a century after its inception.[258]

This may be due to the fact that Bohr himself was so elusive about complementarity, as Rosenfeld has pointed out,

> Complementarity is no system, no doctrine with ready-made precepts. There is no via regia to it; no formal definition of it can even be found in Bohr's writings, and this worries many people.[259]

Rather than a precise definition or system of rules, Bohr often referred to complementarity as a way of thinking. One must learn to "think with complementarity." What we shall see in the next section is that when we do so, we think hermeneutically. We shall see how complementarity, when transferred to the arena of the human sciences, as Bohr intended, bears a striking resemblance to hermeneutic theory.

Thus rather than attempt to explain away the difficulties with complementarity, what would be more profitable is an examination of the attempt by Bohr to apply this kind of thinking to other fields of study. When we do so what we see is that there are undeniable similarities to a more hermeneutic approach to philosophy. What follows is a study of precisely how Bohr intended complementarity to be used in a variety of disciplines outside physics, most important of

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[258] Mara Beller, "The Birth of Complementarity," p. 147.

[259] Léon Rosenfeld, "Niels Bohr's Contribution to Epistemology" in Selected Papers of Léon Rosenfeld, p. 532.

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which will be the understanding of other cultures.

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ii. Complementarity outside Physics

Bohr intended complementarity as the cornerstone of a basic epistemology that would have use in a wide variety of disciplines. Most important for our purposes is the fact that he intended the epistemological lessons gleaned from the quantum situation to be applied to what he felt was the aim and goal of all intellectual pursuits--namely, the understanding of cultures and promotion of general welfare. What Bohr has to say about the way in which one can apply these epistemological lessons, especially the complementary framework, to the understanding of other cultures, bears a striking resemblance not only to the hermeneutic philosophy of Gadamer, as has been emphasized all along, but to the more hermeneutic approach to anthropology one finds in people like Peter Winch and Clifford Geertz.[260] What follows is an examination of such application of complementarity on the part of Bohr, emphasizing the implicit hermeneutic attitude. Then we turn to a brief examination of some of the applications of complementarity to other disciplines as mentioned in Bohr's writings.

Finally, we will see Bohr take all of these attempts to

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[260] See Geertz, Interpretation of Cultures (New York: Basic Books, 1973); and Winch, The Idea of a Social Science and its Relation to Philosophy (Atlantic Highlands NJ: Humanities Press, 1990), and "Understanding a Primitive Society" American Philosophical Quarterly, (1964):307-24. Nevertheless, there will be fundamental differences between Bohr's position and Winch's, that will be made explicit in this chapter.

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show the usefulness of the interpretation of quantum theory for other disciplines to put forth a theory of the "Unity of Knowledge" that is quite different from a Machian "Unity of Science."

-Complementarity and Anthropology:

In 1938 Bohr was invited to give an address to the International Congress of Anthropological and Ethnological Sciences in Copenhagen.[261] He remarks that he approached the task with great hesitation, claiming no first-hand knowledge in these fields, but welcomed the opportunity to draw attention to "the epistemological aspect of the latest development to natural philosophy and its bearing on general human problems."

By now we are familiar with the extraordinary and innovative experiences one encounters in quantum physics. In describing these experiences in this address, Bohr very poetically compares the quantum physicist to a New World explorer. He remarks that

> Our penetration into the world of atoms hitherto closed to the eyes of man, is indeed an adventure which may be compared with the great journeys of discovery of the circumnavigator and the bold explorers of astronomers into the depths of celestial space.[262]

This seems to have been the general attitude of Copenhagen

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[261] "Natural Philosophy and Human Cultures" in Bohr, Vol. II.

[262] Ibid, p. 24.

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physicists, as they displayed a penchant for the extraordinary and iconoclastic, often lauding the boldness of the quantum physicist to test our assumptions and beliefs. One finds Heisenberg, about a decade earlier, expressing the very same sentiment. In praising the boldness of the feats of Christopher Columbus, Heisenberg remarks,

> His most remarkable feat was the decision to leave the known regions of the world and to sail westward, far beyond the point from which his provisions could have got him back home again.
>
> In science, too, it is impossible to open up new territory unless one is prepared to leave the safe anchorage of established doctrine and run the risk of a hazardous leap forward.[263]

Again, the emphasis is on shaking up our traditional beliefs and being <u>open</u> to new experiences.

Most importantly, one must be willing to set sail <u>theoretically</u>, to abandon our familiar assumptions and presuppositions, and be open to the possibility of new answers. One must be prepared for those breaks, ruptures, and surprises we have often mentioned. As Bohr notes in the address,

> In the study of atomic phenomenon we have repeatedly been taught that questions which were believed to have been received long ago their final answers had most unexpected surprises in store for us.[264]

Indeed, this readiness for abandoning "the safe anchorage of

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[263] Werner Heisenberg, "Fresh Fields," in <u>Physics and Beyond</u>, p. 70.

[264] "Natural Philosophy and Human Cultures," in Bohr, <u>Vol. II</u>, p. 25.

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established doctrine" requires adopting the Socratic docta ignorantia that Gadamer often stresses. According to Gadamer, one approaches a dialogue with the openness to the possibility that one's beliefs are wrong. This was the attitude of Bohr in his dialogue with nature. Rather than looking to confirm presuppositions, he sought to discover possible truths. As he often stated of his experimentation, "I did not look for anything, but found it."

Quite similarly, true dialogue for Gadamer, is realizing one can be mistaken. Furthermore, experience for Gadamer is primarily "an experience of negation," a discovery that one's beliefs are inadequate to the subject-matter at issue and hence that one must modify one's point of view. In that respect, Gadamer draws on Hegel's notion of Aufhebung as being an essential component of experience. In the case of quantum theory, experience of negation comes about by realizing our limitations, forcing us to expand our conceptual framework. Thus for Bohr as well experience is a negative event inasmuch as we realize the limitations of our present position.

According to Bohr, this is precisely the function of science in general, and quantum physics in particular--to extend our experiences in such a way where we can test our assumptions, beliefs, and language, and realize their limitations. This position is not merely a Popperian fallibilism whereby we intentionally seek to falsify our theories or claims, but rather one where we are open to the

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possibility that our position might be negated.

What is at work here is the dialectical notion of truth found in hermeneutics. Truth is something that emerges as a result of the interplay between antitheses. In the complementarity framework, truth emerges as a result of the interplay of opposing sides. The dialectical approach to truth is seen as the antithesis of method, indeed as a means of overcoming the tendency of method to prestructure the individual's way of seeing. The realization that some matter is other than one had first thought presupposes that process of passing through questioning. To question genuinely, says Gadamer, means to place in the open because the answer is not yet determined. This was Bohr's attitude not only toward science, but toward understanding in general.

We recall that the quantum situation forces us to be cautious regarding the use of our everyday language. We saw how classical language broke down at the quantum level, and we therefore had to renounce our demand for direct visualization and accept that whatever picturing we do is merely analogical. According to Bohr, the same applies to the judging of other societies. We can only do so from a specific vantage point, immersed in our own conventions, using words that we have given meanings to. Hermeneutics points out that those words that we use may not have the same meaning to other cultures. Regarding this similarly, Bohr points out that,

> Notwithstanding the great separation between our branches of knowledge, the new lesson which has been impressed

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> upon physicists regarding the caution with which all usual conventions must be applied as soon as we are not concerned with everyday experience may indeed by suited to remind us in a novel way of the dangers, well known to humanists, of judging from our standpoint cultures developed within other societies.[265]

We can only understand another metaphorically, in terms of our own conventions and meanings. We always relate back to our meanings and conventions. We are not only suspended in language, as Bohr so often reminds us, but likewise suspended in our conventions.

And yet, like our language, these conventions are invisible to us. We recall that Bohr seems to acknowledge the Gadamerian claim that language is die Mitte through which we understand, and as such it is as invisible to our thought as water is to fish. In that respect we only become aware of it when, like Heidegger's hammer, it breaks down. However, without such a medium as language, thought (and understanding) is not possible. Bohr reminds us that,

> No proper human thinking is imaginable without the use of concepts framed in some language which every generation has to learn anew.[266]

In addition, Bohr applies the so-called "measurement problem" to the understanding of other cultures as well. He claims that just as observation of a sub-atomic particle somehow "disturbs" the particle, so too when one attempts to observe, interpret, and understand the practices of another

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[265] Ibid, p. 13.

[266] Ibid, p. 28.

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culture, one has an undeniable ineliminable influence on precisely what one is trying to understand. He points out that

> In fact, when studying human cultures different from our own, we have to deal with a particular problem of observation which in closer consideration shows many features in common with atomic or psychological problems, where the interaction between objects and measuring tools, or the inseparability of objective content and observing subject, prevents an immediate application of the conventions suited to accounting for experiences of daily life.[267]

The point is, there is no ahistorical, neutral, prejudice-free (culture free) standpoint from which to assess another culture. My prejudices (what Gadamer has called my "horizon of interpretation") will influence (or disturb) the aspect of the foreign culture I am trying to understand (a social practice or ritual, for example) inasmuch as it is my prejudices that are the lens through which I interpret. In trying to understand the practices of another culture, I cannot but alter them since I remain outside of them. That is not to say I cannot understand another culture--just like Bohr never made the claim that we are not observing light in a double slit experiment or electrons in a cloud chamber. Rather, just as the instrument becomes an essential part of the experimental arrangement or description of the phenomena, so too the interpreter influences what he is trying to understand. I disturb--or better stated, constitute--the foreign ritual by making it an object of study. Clifford Geertz describes such

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[267] Ibid, p. 30.

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an anthropological study as a "fictio" or a "making" that the anthropologist creates.[268] The anthropologist is outside the ritual, and yet at the same time it is only an object of study in so far as he considers it as such (constitutes it). Otherwise, it takes place "behind his back" so to speak. Furthermore, just as the experimental arrangement must now take into account the subject (in quantum theory), so too does Geertz' more hermeneutic approach to anthropology insist that the mini-narrative or anecdotal form of the anthropological study include the narrator.[269]

We can likewise correct the use of "disturb" here just the way Bohr does in his quantum theory and instead declare, "any description of an interpretation of a practice of a foreign culture must take into account the conditions under which the interpretation took place." This means an elucidation of the circumstances (historical, cultural, linguistic situatedness) of the interpreter. And yet, as we shall see, this need not usher in relativism.

Along these lines Bohr further states,

> Especially in the study of cultures of primitive peoples, ethnologists not only are, indeed aware of the risk of corrupting such cultures by the necessary contact, but are even contracted with the problem of the reaction of such studies in their own human attitude.[270] (emphasis added)

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[268] Clifford Geertz, Interpretation of Cultures, p. 16.

[269] Ibid, p. 30 ff.

[270] "Natural Philosophy and Human Cultures," in Bohr, Vol. II, p. 30.

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Ironically, Bohr's approach to anthropological study, which he claims to be modeled on the epistemological lessons of quantum theory, bear striking similarities to attempts by both Geertz and Peter Winch to distance anthropology from the methodology of the natural sciences and base it more on the interpretive sciences. In The Idea of a Social Science and Its Relation to Philosophy, Winch asserts that "social information can more profitably be compared to the exchange of ideas in a conversation than to the interaction of forces of a physical system"[271] and "...the way to understand events in human history...is more closely analogous to the way in which we understand expressions of ideas than it is to the way we understand physical processes."[272] Winch's attempts to separate the methodology of the social sciences from the physical in this fashion were quite novel at the time[273], where it was commonly held that cultures were to be understood through underlying general laws.

Quite similarly, in his essay "Unity of Knowledge" Bohr remarks that,

> The decisive point is that, if we attempt to predict what another person will decide to do in a given situation, not only must we strive to know his whole background, including the story of his life in all respects which may have contributed to form his character, but we must

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[271] Peter Winch, The Idea of a Social Science and Its Relation to Philosophy, p. 128.

[272] Ibid, p. 131-2.

[273] Winch does find seeds for his approach in both Weber and Collingwood.

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> realize that what we are ultimately aiming at is to put ourselves in his place.[274]

This assertion is much closer to what one might find in the Verstehen approach in anthropology. (While it might seem like an obvious claim to us, this more hermeneutic approach was fairly novel at the time Bohr espoused it.) And yet, at the same time, by recognizing the inescapability of our own prejudices and cultural situatedness, Bohr was aware that such putting oneself in another's place was not possible.

While Bohr's approach to the understanding of other cultures does seem similar to Winch's claim about the impenetrability of a foreign culture, there is, nonetheless, a fundamental difference. Bohr does not dismiss the possibility of trans-cultural rational criticism the way Winch does, even though understanding and intelligible interpretation are culturally relative.[275] Indeed, by stressing "those features in all civilizations which have their roots in the common situation," Bohr is emphasizing the fact that both dialogue and interpretation are possible. In that respect he is closer to MacIntyre's corrective of Winch (as we shall see below). Consider the following assertion by Bohr:

> Naturally, it is possible to have different forms of speech and thought...just as there are different races or different parts of an organism. But much as all living

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[274] "Unity of Knowledge," in Bohr, Vol. II, p. 78.

[275] See especially Winch's "Understanding a Primitive Society."

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> organisms are constructed in accordance with the same laws of nature, and largely from approximately the same chemical compounds, so the various possibilities of logic are probably based on fundamental forms that are neither man-made nor even dependent on man. These forms must play a decisive part in the selective development of language; they cannot be its mere consequences.[276]

Despite the fact that we are "framework bound" there is nonetheless a rationality as such that can emerge in and through contact with another. This is similar to MacIntyre's position against Winch that there is a rationality qua rationality that can enter in, however obliquely, as an arbiter between cultures. In the 1992 APA Presidential address, MacIntyre declared the following:

> Rationality, understood within some particular tradition with its own conceptual scheme and problematic, as it always has been and will be, nonetheless requires qua rationality a recognition that the rational inadequacies of that tradition from its own point of view...may at any time prove to be such that perhaps only the resources provided by some quite alien tradition...will enable us to identify and to understand the limitations of our own tradition..
> ...rationality requires a readiness on our part to accept, and indeed to welcome, a possible future defeat of the forms of theory and practice in which it has up till now been taken to be embodied within our own tradition...[277]

Georgia Warnke, commenting on these passages, remarks that "such openness to future defeat is what Gadamer means by the

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[276] Quoted in Werner Heisenberg, Physics and Beyond, p. 138.

[277] Alasdair MacIntyre, "Relativism, Power and Philosophy," Presidential Address delivered before the Eighty-first Annual Eastern Division Meeting of the American Philosophical Association, New York, New York 29 December 1984; in Proceedings and Addresses of The American Philosophical Association (APA, Newark, Delaware, 1985), p. 19.

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openness that issues from the hermeneutic experience of negation. Both MacIntyre and Gadamer define rationality, then, as a willingness to admit the existence of better options. The awareness that one's knowledge is always open to refutation or modification from the vantage point of another perspective is not a basis for suspending confidence in the idea of reason but rather represents the very possibility of rational progress."[278] Bohr too remarks on the importance of recognizing better options, and his point is that being open to new experiences in the natural sciences is what primes us for such an openness in the understanding of other cultures.

This is all consistent with Gadamer, who, quite unlike Rorty, acknowledges an "emergent rationality." It is through dialogue with other cultures that we can learn to be rational. In that respect Gadamer doesn't completely abandon the Enlightenment ideal--that is, he is not as relativistic as people like Habermas and most recently, James F. Harris[279] try to make him out to be. Rather, Gadamer makes rationality as such compatible with the cultural, historical, and linguistic embeddedness of our understanding. It is through the interaction with other cultures, both past and present,

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[278] Georgia Warnke, Gadamer: Hermeneutics, Tradition and Reason, p. 173.

[279] See especially Harris' recent book Against Relativism: A Philosophical Defense of Method (La Salle, Ill: Open Court Publishing Co., 1992).

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that, according to Gadamer, rationality as such can emerge.[280]

For Bohr it is the framework of complementarity that enables us to break out of the morass of relativism, despite the cultural embeddedness of viewpoints and perspectives. He notes that

> The main obstacle to an unprejudiced attitude toward the relation between various human cultures is, however, the deep rooted differences of the traditional backgrounds on which the cultural harmony in different societies is based and which exclude any simple comparison between such cultures.
> It is above all in this connection that the viewpoint of complementarity offers itself as a means of coping with the situation.[281]

Complementarity allows us to break out of Rorty's "frank ethnocentrism" even though we remain culturally conditioned. And it is the proper function of dialectical understanding to help us break out.

Borrowing from the quantum situation, Bohr makes the claim that "different cultures are complementary to each other." He states that

> Using the word much as it is used, in atomic physics, to characterize the relationship between experiences obtained by different experimental arrangements and visualizable only by mutually exclusive ideas, we may truly say that different human cultures are

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[280] This, however, like our commitment to (metaphoric) realism and truth, may remain on the level of wish-fulfillment. In that respect, we may be forced to admit to a fideism with regard rationality as well.

[281] "Natural Philosophy and Human Cultures," in Bohr, Vol. II, p. 32.

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complementary.[282]

As such, each culture articulates a possible way which human life may manifest itself. Bohr concludes his 1958 essay entitled "Quantum Physics and Philosophy"[283] with the assertion that "the integrity of living organisms and the characteristics of conscious individuals and human cultures present features of wholeness, the account of which implies a typical complementarity mode of description."[284] It is precisely this wholeness that Bohr would like to attribute to both individuals and cultures that points one in the direction of hermeneutics. Complementarity works within the part-whole relationship. Thus one aspect, one side of the complementary relation can be considered only in reference to and against the background of the whole, which includes not only the alternative or contrary of the complementary component, but the possibility for future possibly different aspects or components as well. In that respect, calling different cultures "complementary" means that in order to understand what it means to be human (and likewise what it means to be rational) requires interaction with other cultures. It is in and through such interaction that we can come to realize that no one culture can express the essence of what it means to be

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[282] Ibid.

[283] "Quantum Physics and Philosophy: Causality and Complementarity" in Bohr, Vol. III.

[284] Bohr, Vol. III, p. 78.

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human. Bohr points out that

> Indeed, each such culture represents a harmonious balance of traditional conventions by means of which latent potentialities of human life can unfold themselves in a way which reveals to us new aspects of its unlimited richness and variety.[285]

If we tease out the implications that means each culture reveals aspects of the phenomenon of human life. Each (all) being necessary for the full comprehension of what it means to be human. This fosters an attitude of tolerance as we are open to the possible truths other cultures can reveal. Likewise, no one culture can be considered privileged. We can, pace Rorty, extinguish ethnocentrism.[286]

We see how useful the framework of complementarity can be for articulating both the situatedness of all intercultural understanding, and the requisite openness to possible truth one may encounter. Nevertheless, as Bohr is quick to point out, there are limitations to this application of

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[285] "Natural Philosophy and Human Cultures," in Bohr, Vol. II, p. 30.

[286] This tolerance, however, should not be taken for a blind acceptance of injustices such as slavery, subordination of women, genital mutilation, and genocide, that have all been accepted features of different cultures at different times. However, by adopting the hermeneutic approach one maintains that it is through contact with other cultures, especially dialogical contact, that one eventually comes to recognize these unjust and dehumanizing practices as the result of the sorts of prejudices that need to be eliminated. It is often the case that societies where such injustices as listed above have been known to prevail are ones that have by and large attempted to maintain a kind of isolationism from others. For example, one thinks of the Iranian culture after the deposing of the Shah, and its unwillingness to be exposed to other cultural practices.

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complementarity. For all the similarities between the complementarity at work in understanding wave-particle dualism and that at work in the understanding of other cultures, there is, nonetheless, one essential difference. That is precisely in the ability to emend one's tradition--to change one's prejudices through dialogue, and to effect, in Bohr's own words, a "fusion of traditions." Cultures are not mutually exclusive the way wave and particle descriptions are. Since, as Bohr points out, no culture is fully self-contained, there can be a "fusion of traditions" through intimate contact. Bohr calls for interaction, emigration and cultural conquest (appropriation) as being some of the most essential ways of overcoming prejudices that can inhibit progress and humanistic advance. This is the function of dialogue in Gadamer's hermeneutics, and culminates in what he refers to as Bildung. The function of hermeneutics is education rather than justification. It does not attempt to legitimate our beliefs but rather, as Rorty describes it, tries to "take us out of our old selves by the power of strangeness" and "aid us in becoming new beings."[287]

Gadamer explores the this notion of Bildung in the section of Truth and Method entitled "The significance of the humanist tradition." He describes the function of Bildung as fostering an awareness of different possibilities of coping

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[287] Richard Rorty, Philosophy and the Mirror of Nature (Princeton: Princeton University Press, 1979), p. 360.

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with the world, of different life-options, and new modes of self-description. The proper function of understanding is to create individuals that are gebildete, or cultured. The gebildete person is one who has moved beyond the limits of the interests of his or her community or group to adopt an interest in world history, different cultures and the past. In that respect, there is a similarity between this notion of Bildung and John Stuart Mill's emphasis on the "cultivated mind" and how a lack of cultivation is most often the source of an unsatisfactory life. To quote Mill,

> Next to selfishness, the principle cause which makes life unsatisfactory, is want of mental cultivation. A cultivated mind--I do not mean that of a philosopher, but any mind to which the fountains of knowledge have been opened, and which has been taught, in any tolerable degree, to exercise its faculties--finds sources in inexhaustible interest in all that surrounds it; in the objects of nature, the achievements of art, the imaginations of poetry, the incidents of history, the ways of mankind past and present, and their prospects in the future.[288]

Quite similarly, Bohr emphasizes cultural development and awareness not only for individual betterment, but as a means to the amelioration of the human condition in general. He states that

> It is indeed, perhaps, the greatest prospect of humanistic studies to contribute through an increasing knowledge of the history of cultural development to that gradual removal of prejudices which is the common aim of all science.[289]

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[288] John Stuart Mill, Utilitarianism and Other Essays (New York: Penguin Books, 1987), p. 285.

[289] "The Unity of Human Knowledge," in Bohr, Vol. III, p. 15.

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Again, it is the function of Bildung to eliminate such distorting prejudices.

Georgia Warnke describes the importance of Bildung in Gadamer's thought as follows:

> In studying other cultures, performing scientific experiments, writing poetry and examining one's own history, what one learns is not a series of unrelated and irrevocably true facts. Rather, to the extent that one can avoid an epistemological architectonic, to the extent, in other words, that one can transcend questions involving the soundness of one's method or the validity of one's finding, what one achieves is a capacity for future learning, for new ways of thinking, speaking, and acting. One learns that one's own historical horizon is part of an endlessly articulated and shifting universe of horizons and that to try to fix this universe in a final, immutable form or hierarchy is to miss the point.[290]

This is a sentiment Bohr repeatedly expresses. He emphasizes the openness to future learning, new ways of thinking, and the capacity it can have for our mutual understanding, or what he often calls "the elevating of human culture." It is this mutual understanding through entering into dialogue with other cultures and trying to bring about fusions that Bohr believes is essential, especially in the age of the rapid progress of science and technology. Indeed, he seems to evince a very keen appreciation for the promotion of practical deliberation over and above technical reason that so preoccupies Gadamer. Throughout his work, Gadamer points to the increase in social irrationality which accompanies the hegemony of technical reason over practical deliberation. It is in that respect

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[290] Georgia Warnke, Gadamer: Hermeneutics, Tradition and Reason, p. 170.

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that he tries to resuscitate Aristotle's notion of phronesis, making application a moment, or part of, understanding. As Gadamer often states, we are the inheritors of phronesis, of practical knowledge. And according to both Gadamer and Bohr one can gain practical knowledge by a recognition of the multifariousness of the human position in and through the openness of dialogue. What this return to practical rationality eventually yields is solidarity--"the type of solidarity, participation, and mutual recognition that is founded in dialogical communities."[291]

According to Gadamer, what we learn are tact, taste, and judgment, and by virtue of them we learn to discriminate between good and bad, right and wrong, important and unimportant. As he states in Truth and Method, "Whoever has sound judgment is not enabled primarily to judge particulars under universal viewpoints; instead he knows what is important."[292]

While we notice the similarities between Bohr and Gadamer regarding the emphasis on culture and education for the betterment of mankind, what is unique in the thought of the former is the claim that we have the situation in quantum physics to serve as a model for the kind of thinking that

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[291] Richard Bernstein, Beyond Objectivism and Relativism, p. 231.

[292] For Gadamer, this means a return to the Greek virtues and the ideal of the "good life" of areté. (This remains a topic for another study.)

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brings about such culture and education. Just as we must be open to the possibility of light manifesting itself in another guise in a specific experimental arrangement, so too we must be open to the possibility of a different culture, with its distinct conventions as being an expression of humanity and human spirit. In that respect, although Bohr does not himself address the issue, we must be open to different rationalities at work in different cultures. Our rationality can change, indeed that is the point about expanding our conceptual framework. The metaphor of encountering a foreign land described at the outset is essential here. The point is just as we had to expand our conceptual framework with complementarity so as to be able to accommodate novel experiences, (even those that seem to run counter to our logical principles), so too, when encountering another culture we must be able to think more liberally, accept the possibility that there may very well be a different rationality at work, and accept the fact that even if their rationality or practices run counter to ours, or even if they seem to contradict ours, they are nonetheless an essential expression of humanity and as such should be accommodated.[293] Just as it is new experiences that may show the insufficiency of our present conceptual frameworks, it is precisely encounters with new cultures that show the insufficiency of our prejudices and presuppositions. As Bohr

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[293] Within limits, of course.

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notes, "All knowledge presents itself within a conceptual framework adapted to account for previous experience and that any such framework may prove too narrow to comprehend new experience." We now see that this applies to all fields of study and domains of experience.

Despite the possibility of different rationalities at work, that does not mean that we cannot compare or assess. And most importantly, that does not mean that there is not a rationality gua rationality that cannot enter as arbiter. But, as is emphasized by Gadamer, such a rationality is not already fixed. Rather it emerges in and through the encounter, or dialogue. For both Bohr and Gadamer alike, openness to the constant possibility of developing one's perspective or expanding one's conceptual framework is a crucial feature of rationality itself.

Remarking on this conception of rationality, Georgia Warnke notes,

> Both MacIntyre and Gadamer define rationality, then, as a willingness to admit the existence of better options. The awareness that one's knowledge is always open to refutation or modification from the vantage point of another perspective is not a basis for suspending confidence in the idea of reason but rather represents the very possibility of rational progress.[294]

But, as we have seen, rational progress is contingent upon the "really critical question of hermeneutics"--namely--that of separating "the true prejudices by which we understand from

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[294] Georgia Warnke, Gadamer: Hermeneutics, Tradition and Reason, p. 173.

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the false ones by which we misunderstand."

It is quite remarkable that both Bohr and Heisenberg display a Gadamerian appreciation for the notion of "prejudice" as well. We recall that for Gadamer prejudices are essential. Without prejudices of some sort, understanding cannot take place. He understands "prejudice" as it is intended in the German sense of Vor-urteil--literally, a "pre-judgment, or making a judgment before all the evidence has been adequately assessed. In that respect, some prejudices can be confirmed or justified. It is the point of Bildung and dialogue to discriminate between those prejudices that enable us to understand, those that form the horizon of our interpretation from which we enter into dialogue, and those prejudices on the other hand, that distort and inhibit proper dialogue. It is precisely those latter sorts of prejudices that become the basis for force, coercion, and manipulation, and it is precisely then that we need the ideological critique of Habermas or the psychoanalytic of Apel. At the end of his address to the Anthropological Society, Bohr, after having used the term prejudice quite in the way Gadamer intended it (as the enabling conditions for understanding), had to explain himself in the following fashion:

> In order to explain to an audience that I did not use the word prejudice to imply any condemnation of other cultures, but merely to characterize our necessarily prejudiced conceptual frame, I referred jokingly to the traditional prejudices which the Danes cherish with regard to their Swedish brothers on the other side of the beautiful Sound outside these windows, with whom we have fought through centuries even within the walls of

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> this castle, and from contact with whom we have, through the ages, received so much fruitful inspiration. Now you will realize what a shock I got when, after my address, a member of the audience came up to me and said that he could not understand why I hated Swedes.[295]

It is precisely this rather primitive understanding of the hermeneutic situation which prevented Bohr from being able to articulate precisely what he meant. Understanding cannot take place without prejudices of some sort. In that respect Bohr is once again jettisoning the Enlightenment ideal of a prejudice free position. But like the pre-Socratics whom Aristotle chided for not appreciating the full import of what they said, Bohr seems to be lisping his hermeneutic theory rather than stating it fully.

Quite similarly, Heisenberg seems to appreciate the essential nature of prejudices for understanding in all fields of research. In his work entitled Tradition in Science, he makes the following claim,

> Since it has been my task to speak about the role of tradition in science, I have to ask whether tradition has really been only a hindrance in these developments, whether it has merely filled the minds of scientists with prejudices, the removal of which was the most important condition for progress. At this point the problem arises from the word prejudice. When we speak about our investigations, about the phenomena we are going to study, we need a language, we need words, and the words are the verbal expression of concepts. In the beginning of our investigations, there can be no avoiding the fact, that the words are connected with the old concepts, since the new ones don't exist. Therefore these so-called prejudices are a necessary part of our language, and cannot simply be eliminated. We learn language by tradition, the traditional concepts from our

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[295] "Natural Philosophy and Human Cultures," in Bohr, Vol. II, p. 31.

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> way of thinking about the problems and determine our questions.[296]

Heisenberg goes on to make the claim that such prejudices are the very condition not only for understanding, but for progress in science. And he regrets that there is no other word than "prejudice," which so often evokes such negative connotations.

-Complementarity and the other sciences:

Bohr saw complementarity as an important conceptual tool not only for making sense of the quantum situation, but as indispensable for solving dilemmas in all fields of inquiry. He never abandoned the notion and indeed envisioned a day when complementarity would be a universally accepted principle that would be taught in schools. Rosenfeld notes that "Bohr devoted a considerable amount of hard work to exploring the possibilities of application of complementarity to other domains of knowledge; he attached no less importance to this task than to his purely physical investigations, and he derived no less satisfaction from its accomplishments."[297]

The field of application for complementarity outside physical science that most interested Bohr was psychology, as he often drew from psychological phenomena for an elucidation

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[296] Werner Heisenberg, Tradition in Science (New York: The Seabury Press, 1983), p. 15.

[297] Léon Rosenfeld, "Niels Bohr in the 30's," in Selected Papers of Léon Rosenfeld, p. 120.

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of the quantum situation. There is a sense in which the complementary aspects of the self are similar to the Kantian distinction between the empirical and transcendental egos.

We have already mentioned the difficulty Bohr noted in trying to examine a part of consciousness, and the fact that one is there reminded of both the measurement problem and the Eastern dictum that we are both actors and spectators in the drama of existence. In addition, Bohr often commented on the similarities inherent in the attempt to discuss our emotions. He states that

> Indeed the impossibility in psychological experience to distinguish between the phenomena themselves and their conscious perception clearly demands a renunciation of simple causal description on the model of classical physics, and the very way in which words like "thoughts" and "feelings" are used to describe such experience reminds one most suggestively of the complementarity encountered in atomic physics.[298]

And further,

> We all know the old saying that, if we try to analyze our own emotions, we hardly possess them any longer, and in that sense we recognize between psychical experiences, for the description of which words such as "thoughts" and "feelings" are adequately used, a complementary relationship similar to that between the experiences regarding the behavior of atoms obtained under different experimental arrangements and described by means of different analogies taken from our usual ideas.[299]

Bohr likewise applied the framework of complementarity to the problem of free-will versus determinism:

> It might still be permitted here briefly to refer to the relation which exists between the regularities in the

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[298] Bohr, Vol. II, p. 22.

[299] Bohr, Vol. II, p. 27.

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> domain of psychology and the problem of the causality of physical phenomena. When considering the contrast between the feeling of free will, which governs the psychic life, and the apparently uninterrupted causal chain of the accompanying physiological processes, the thought has, indeed, not eluded philosophers that we may be concerned here with an unvisualizable relation of complementarity.[300]

Interestingly enough, the one field of study where Bohr developed complementarity most systematically was biology, probably out of deference to his father and the mechanism versus vitalism debated that so preoccupied him. It was precisely a harmonizing of the two positions that the elder Bohr had proposed--and no doubt this suggestion influenced the directions his son's thought took. As Rosenfeld points out,

> In the past two points of view, under varying forms, have always been put in sharp opposition to each other, the general opinion being that one of them had to prevail to the exclusion of the other, that there was not room for both in the science of life. Niels Bohr could now point out that this last belief was only the result of a conception of logic which the physicists had recognized too narrow, and that the wider frame of complementarity seemed particularly well-suited to accommodate the two standpoints, and make it possible without any contradiction to take advantage of both of them, quite in the spirit of his father's ideas.[301]

Thus in cases involving the "free-will/determinist" controversy in psychology and the "mechanistic/vitalistic controversy in biology Bohr believed that the resolution of the dispute, like the case of wave-particle dualism, would not involve a victory for one side or the other, but would

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[300] Bohr, Vol. I, p. 100.

[301] Léon Rosenfeld, "Niels Bohr in the 30's," in Selected Papers of Léon Rosenfeld, p. 132-3.

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necessitate "a renewed examination" of "the possibilities of observation and definition." It is interesting to note that this line of thinking also applied to the "nature versus nurture" controversy in cultural anthropology, but was never fully developed by Bohr and according to Folse was strongly colored by Bohr's desire to counter Nazi racial theories at the time.[302]

Thus we see that according to Bohr, the situation in quantum physics is only one reflection of an all-pervasive principle. Bohr emphasizes the universal significance of complementarity. Again, Bohr's point is that complementarity teaches us a lesson about the use of concepts for describing all phenomena Any situation where the logical framework is too narrow to accommodate varying descriptions of the same phenomena, one appeals to the framework of complementarity. Complementarity allows us to use seemingly incompatible descriptions that nonetheless both prove indispensable in describing experience.

But Bohr is quick to point out that by stressing the universality of complementarity he is not evoking any kind of mysticism foreign to the spirit of science, nor is he collapsing science into psychology, as he states,

> By such a comparison it is, of course, in no way intended to suggest any closer relation between atomic physics and psychology but merely to stress an epistemological argument common to both fields, and thus to encourage us

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[302] See Henry J. Folse, The Philosophy of Complementarity.

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> to see how far the solution of the relatively simple physical problems may be helpful in clarifying the more intricate psychological questions with which human life confronts us, and which anthropologists and ethnologists so often meet in their investigations.[303]

Again, the point is not to collapse the distinction between the human and natural sciences completely, but rather to draw on and elucidate similarities. We as human thinkers use the same operations of thought and understanding regardless of the subject matter or discipline. We recall that it was stated that our assertion at the outset of this study that the natural sciences were equally hermeneutic makes a claim not about the meaningfulness of the objects of study, but rather about us as human knowers. The point is that understanding is a ubiquitous feature of all our activities. This is the basis for Bohr's claim to the "Unity of Knowledge." Since we understand through language, and secure objectivity by means of communication, there is always interpretation going on as well as conveying of meaning. Bohr's point (as mentioned above) is that since it is the case that there is a "unity of knowledge" at work, why not draw upon conclusions in one field of study for use in solving problems in another--possibly far removed or traditionally polar--discipline. This is precisely what Bohr seems to be doing, and more importantly, bidding us to do. Perhaps most importantly, Bohr's thought is a reminder of Gadamer's claim that whenever we attempt to examine the ground we are standing on, there we are engaged in hermeneutic

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[303] Bohr, Vol. II, p. 27.

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reflection.

There is, nonetheless, the specter of relativism hovering over the framework of complementarity. After all, it seems as if complementarity allows us to establish the validity of any two competing descriptions or interpretations. This is the case neither for Bohr nor for Gadamer. One cannot haphazardly invoke the notion of complementarity in a sort of ad hoc fashion so that any two antithetical positions can co-exist. Nor do we want to be accused of dragging it in as a deus ex machina when at a loss for a solution. Rather, there are certain criteria that must be fulfilled. In the case of quantum theory, the criteria of predictability and fruitfulness were factors. The reason why the wave and particle descriptions were given equal footing is that both were indispensable in explaining and predicting. Likewise, with competing interpretations or descriptions there is a pragmatic element that looks to what the competing positions allow us to do. And most important are those interpretations that point beyond themselves toward further possible descriptions and keep the conversation going. As Gadamer emphasized it is the function of discourse and time to eliminate the inessential.[304] In that sense what complementarity does is provide us with a way of preparing for the possibility of being wrong. It gives us a sense of

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[304] Again, we are aware that this remains at the level of wish-fulfillment.

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tolerance, and most importantly, is a way to reject essentialism or Cartesian foundationalism and dogmatism.

Other dichotomies Bohr intended to invoke complementarity to harmonize were justice versus charity, instinct versus reason, and justice versus love. Bohr never lived to see the extension of complementarity to all fields as he so hoped, and according to Léon Rosenfeld, many commentators of Bohr's thought lose sight of the important role it played for him. As Rosenfeld describes it,

> Bohr had great expectations about the future role of complementarity. He upheld them with unshakable optimism, never discouraged by the scant response he got from our unphilosophical age. On one of those unforgettable strolls during which Bohr would so candidly disclose his innermost thoughts, we came to consider that what many people nowadays sought in religion was guidance and consolation that science could not offer. Thereupon Bohr declared, with intense animation, that he saw the day when complementarity would be taught in the schools and become a part of general education; and better than any religion, he added, a sense of complementarity would offer people the guidance they needed.[305]

In this respect, it is quite fascinating that one finds perhaps an earlier version of complementarity at work in the thought of Thomas Aquinas. We recall that in order to preserve the integrity of the Aristotelian cosmology and natural philosophy, and at the same time maintain the sacredness of Christian doctrine, which, were often diametrically opposed to each other, Aquinas suggests that the two explanations are "complementary." Both Aristotelian

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[305] Léon Rosenfeld, "Niels Bohr's Contribution to Epistemology" in Selected Papers of Léon Rosenfeld, p. 535.

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natural philosophy and Christian theology are necessary for articulating truth. There is a sense in which one can read Aquinas as appealing to something like complementarity to allow for the validity of different experiences he had--the philosophical and the theological--even though the more orthodox interpretation is that he allowed the latter to overshadow the former.[306] Furthermore, we recall that for Aquinas, one uses the language of everyday life (philosophy) analogically, when talking about God, much in the way we must use our classical concepts analogically in quantum descriptions.[307] While it is most probable that Aquinas is a philosopher Bohr did not read, the point is that the notion of complementarity and the more dialectical way of thinking is not quite as new as Bohr may have thought.

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[306] The point is that if the theological were enough, Aquinas would never have seen fit to pursue the philosophical. But this remains the topic of another study.

[307] That certainly is not to say that with atoms their essence and existence are one (!), but rather to point out a similar way of harmonizing different descriptions where both reveal aspects of the same reality.

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iii. The Unity of Knowledge

Finally, Bohr attempts to relate all this to a theory of the Unity of Knowledge. He addressed the issue in two different essays. The first entitled "Unity of Knowledge" (mentioned above) was an address delivered at a conference in October 1954 in connection with the Bicentennial of Columbia University. There Bohr makes the claim that

> The epistemological lesson contained in the development of atomic physics reminds us of similar situations with respect to the description and comprehension of experience far beyond the borders of physical science, and allows us to trace common features promoting the search for unity of knowledge.[308]

Such a unity of knowledge was to be constructed on the basis of the necessity for communication and the framework of complementarity.

Interestingly, in this essay Bohr even considers whether there is such a thing as poetical or spiritual or cultural truth distinct from scientific truth. He concludes that the poetical, etc., are essential for balancing out the scientific. The poetical and spiritual inspire the scientific and give it possible directions, especially since man is a "thing variable" to paraphrase Bacon. There are different aspects to humans that all need to be addressed. Bohr points out that one can even apply the framework of complementarity to address the necessity of both seriousness and humor in our lives, comparable to the balancing of children's play and

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[308] "Unity of Knowledge" in Bohr, Vol. II, p. 68.

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maturity. Both are important aspects of being human, and both should be given their due.[309] Bohr remarks that

> Indeed, if we always endeavor to speak quite seriously, we run the risk of very soon appearing ridiculously tedious to our listeners and ourselves, but if we try to joke all the time, we soon find ourselves, and our listeners too, in the desperate mood of the jesters in Shakespeare's dramas.[310]

By applying the framework of complementarity we can do justice to different aspects of what it means to be human. What this application is eliminating is the concept of essentialism in any field of study and, as was stated above, promotes an attitude of tolerance and understanding. In that respect, the goal of Bildung and the Unity of Knowledge are intimately connected, as Bohr notes in the conclusion of his address,

> In fact, not only has contact between nations often resulted in the fusion of cultures retaining valuable elements of national traditions, but anthropological research is steadily becoming a most important source for illuminating common features of cultural developments. Indeed, the problem of unity of knowledge can hardly be separated from the striving for universal understanding

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[309] It is interesting to note that the framework of complementarity, and this notion of different and equally essential aspects of a person, as well as of cultures, is quite consistent with contemporary attempts to construct a feminist ontology along the lines of an "aspect theory of the self" one finds in the work of people like Caroline Whitbeck and Ann Ferguson. See especially Caroline Whitbeck, "A Different Reality," and Ann Ferguson, "An Aspect Theory of the Self," both in Garry and Pearsall, eds., Women, Knowledge and Reality. Likewise, there are striking similarities between this position and the more hermeneutic philosophy of science one finds in the work of Evelyn Fox Keller, especially in the substitution of the notion of a "dialogue with nature" for the more traditional conception of science as "domination and control over nature."

[310] "Unity of Knowledge," in Bohr, Vol. II, p. 79-80.

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as a means of elevating human culture.[311]

Bohr returned to this topic of the Unity of Knowledge in 1960 in an address delivered at the Congress in Copenhagen arranged by La Fondation Europeenné de la Culture[312]. He begins the address by stating that the topic of the unity of knowledge is a question that is as old as civilization itself. And it is precisely the advances in quantum physics that have given this most essential topic a new perspective. In that sense, the advances in quantum theory have brought the Geisteswissenschaften and the Naturwissenshaften closer together, as Bohr remarks,

> In our century the immense progress of the sciences has not only greatly advanced technology and medicine, but has at the same time given us an unsuspected lesson about our position as observers of that nature of which we are part ourselves. Far from implying a schism between humanism and physical science, this development entails a message of importance for our attitude to common human problems, which--as I shall try to show--has given the old question of the unity of knowledge a new perspective.[313]

This new perspective that Bohr speaks of is one that draws the similarity not from the direction that the positivists attempted, in the spirit of a Machian "unity of science" but rather draws on the common humanistic elements in all fields of study. Indeed, in an earlier essay Bohr had warned against interpreting the features of wholeness that quantum theory

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311 "Unity of Knowledge," in Bohr, Vol. II, p. 81.

312 "The Unity of Human Knowledge," in Bohr, Vol III.

313 Ibid, p. 8.

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introduces as countenancing the positivist tide that would eliminate metaphysical concerns and reduce the human sciences to the more verifiable physical. Along with this criticism goes an admonition against the methodological concerns of the Cartesian system. As Bohr notes,

> Owing to the diversified use of the rich vocabulary available for communicating of experience in those wider fields, and above all to the varying interpretations, in philosophical literature, of the concept of causality, the aim of such comparisons has sometimes been misunderstood.[314]

And indeed Bohr points to the importance of on drawing humanistic fields of study, especially art, for inspiration, as he notes,

> Such considerations involve no lack of appreciation of the inspiration which the great creations of art offer us by pointing to features of harmonious wholeness in our position. Indeed, in renouncing logical analysis to an increasing degree and in turn allowing the play on all strings of emotion, poetry, painting an music contain possibilities of bridging between extreme modes as those characterized as pragmatic and mystic.[315]

In conclusion, we repeat Bohr's sentiment at the end of the earlier essay on the "Unity of Knowledge,"

> The problem of unity of knowledge can hardly be separated from the striving for universal understanding as a means of elevating human culture."[316]

We can now see the keen appreciation Bohr had for those

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[314] "Quantum Physics and Philosophy," in Bohr, Vol. III, p. 7.

[315] "The Unity of Human Knowledge," in Bohr, Vol. II, p. 14.

[316] "Unity of Knowledge," in Bohr, Vol. II, p. 81.

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three elements of Gadamerian hermeneutics that are so essential: Dialogue, Experience, and Bildung. Bohr emphasized the fact that in the quantum situation are the seeds for a philosophy, and I have tried to show that this philosophy is quite similar to a philosophical hermeneutics. While there is no way Bohr could have been familiar with Gadamer's work in Truth and Method (the work did not appear until 1960), nevertheless, the similarities are striking. The point is, if we applied the epistemological lessons of quantum theory to other fields of inquiry the way Bohr suggested, what we would end up with is something quite similar to a philosophical hermeneutics.

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