Laudan's Model of Axiological Change and the Bohr-Einstein Debate[1]

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1. Overview of Laudan's Model of Axiological Change

Since the publication of *Science and Values* in which Laudan unveiled his "reticulated model of scientific change" (Laudan (1984)), he has published a series of articles emphasizing the *naturalistic axiology* inherent in this model. (Laudan (1986), (1987a), (1987b), (1989), and (forthcoming)). His *epistemic naturalism* makes the business of fixing rational beliefs about facts, theories, methodologies, and aims all together "cut from the same piece of empirical cloth." Laudan's position has numerous attractive qualities: It allows one to accept a great deal of the wisdom in historicism without caving in to relativism. It allows one to accept the seemingly inevitable annexation of the theory of knowledge by the sciences and yet still maintain a normative epistemology. Finally, it awakens philosophers of science's dogmatic slumbers regarding the axiology of scientific inquiry, and stimulates historical research into the relation between practiced means and professed ends in the sciences.

In this paper I explore the application of Laudan's model to the Bohr-Einstein debate on the acceptability of quantum mechanics, not as a test of the model's adequacy, but as a means of enlightening what is at issue in this collision of canonical giants. To be sure, to whatever extent that I do find the shoe fits, I am inclined to think Laudan's model approximates the truth about change in science; however to the extent that I disagree with the conclusion that this episode teaches the abandonment of the goals of realism, as I conceive that polyfaceted outlook, my analysis goes against a primary lesson Laudan would like to draw from his account of change.

1.1 Laudan's Naturalistic Axiology

Laudan argues it is a mistake to believe epistemological naturalism requires surrendering the normative task of stipulating *methodological rules*. Such rules are understood as *hypothetical* imperatives in which the method we *ought* to employ is the contingent consequence of antecedent *epistemic aims*. In Laudan's "reticulated model of scientific change" not only do we have the old theory-ladeness circle: facts constrain theory choice but theories tell us what are the facts. Now we add two more loops: on the epistemic level belief-fixing methodologies select theories, but the success or failure of selected theories in prediction and control informs the choice of appropriate epistemic methodologies. On an axiological level epistemic goals constrain

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choice of methodologies, while the empirical success or failure of methodologies informs us about what epistemic goals we *ought* to pursue. Thus Laudan grounds his naturalistic epistemology in a naturalistic axiology and brazenly committing the naturalistic fallacy, claims to derive an "ought" from an "is."

Although the choice of epistemic aims is by no means determined by *narrowly* empirical factors (*Cf.* Laudan (forthcoming) for his reply to this objection), Laudan argues that the historical development of empirical knowledge embodied in successful science constrains the choice of epistemic goals, because the truth or falsity of methodological claims about means-ends connections is determined by their actual success or failure in attaining the desired end by employing the asserted means. When experience reveals that employing a method no longer is conducive to the end for which it was originally adopted, the epistemic precept must be modified. We learn what we *ought* to do, from the way the world *is*. Epistemology can remain prescriptive and yet cut from the same empirical cloth as the sciences.

However, Laudan naturalizes normativity only by "passing the buck" to the axiological level. A naturalized epistemology is opened and evolving like any other science. We can, and history reveals we have, replaced one method with a better one for achieving the same cognitive goal. But why ought we pursue the *same* goal? When experience reveals an adopted methodology fails to achieve a stated end, we need not reject the epistemic methodological consequent of the conditional. Particularly when an established method is effective at achieving some *other* (perhaps originally unintended) goal, we may choose to keep the methodology and abandon -for essentially *empirical* reasons- our antecedent aim. Thus we come to view the existing methodological practice as justified by its success in achieving the formerly unintended, but now proclaimed *new* goal which it is successful in achieving.[2]

In effect, Laudan makes the choice of goals a matter of natural knowledge by appealing to an implicit definition of "rationality." The epistemic methods adopted by a *rational* inquirer must be ones which are conducive to stated aims; those which are not can be considered as "refuted" by experience. The scientifically rational inquirer will pursue no wild geese and frowns of quixotic quests. So if the development of our scientific beliefs leads us to conclude that an epistemic aim once thought worthy of pursuit is in fact not attainable, or attainable only with significant loss of previously acceptable belief, it is not rational to pursue such a goal and those methodologies for fixing belief contingent on the assumption of such a goal, ought to be attached to some other goal or abandoned (*Cf.* Laudan (1989)).

A naturalistic axiology must exhibit the rational process by which the exploration of nature has come to select and revise the cognitive aims which adjudicate the choice of actual methodological practices embodied in the concrete history of scientific inquiry. Although presumably Laudan would admit that the historical evidence could have gone otherwise, in fact he argues that the record of that history reveals that scientific inquiry is not motivated by goals forming a timeless essence laid bare in the one true epistemology. Of course new aims may well be dressed up in the same old names of "Knowledge" and "Truth" and paraded around as our "real" goal all along, but this is only the verbal smokescreen by which the present engulfs the past.[3] Though the high priests of the tradition may talk of an unceasing quest for "Knowledge" or "Truth," the different conceptions of these "essential" goals are as numerous and varied as the conceptual schemes employed by the sciences over the centuries.

1.2 Naturalistic Axiology and Realism

Since Laudan makes questions of epistemic methodology a subject for naturalistic investigation by yoking it to the axiology of inquiry, we should expect on the

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Laudanian model that when scientists are unable to agree at the methodological level, they will engage in an "axiological ascent" to debate the *aims* of their inquiry. However, in admitting change in the basic aims of science, the defender of scientific rationality can defend against relativism only by exhibiting a normative rationality governing the dynamics of change in the choice of basic aims.[4] To say that relativism can be countered by a naturalizing move at this level is to ground that *normative rationality* in the objective nature of the dialectical interplay between the development of scientific belief and the natural world which it seeks to comprehend. The heart of naturalistic axiology lies in the claim that the rational inquirer changes the aims of inquiry because in learning about the world, one learns which epistemic goals can be successfully pursued and which cannot. Laudan saves historicist epistemology from the slippery slope to relativism by anchoring the selection of cognitive goals in what we learn about the-way-the-world-is.

Laudan's view can be seen as a kind of Popperianism at the axiological level. While we never confirm or prove any cognitive aims as *the* ones we ought to pursue, we learn to exclude unattainable goals as the ones we ought to *abandon*. The Popperianism and the naturalism seem to me to combine to point towards realism in the interpretation of scientific knowledge. Since the-way-the-world-is, insofar as science can learn about it, constrains science's rational aims, which in turn constrains the epistemic methodologies employed for the fixation of scientific belief, the beliefs which result from such an historical process will move, at least asymptotically, to an ever greater conformity with a rational conception of the-way-the-world-is. Such a view is "realistic" in that it would treat the acceptance of scientific beliefs as ultimately contingent on prior acceptance of beliefs about the-way-the-world-is, even though, in a great circle, those beliefs are arrived at from theories selected by methods derived from the aims in question.

The realist can defend the realist aim as essential because in actual fact real research will not be motivated by a single aim, but by a whole bouquet of seemingly compatible aims which further empirical progress could well reveal to be incompatible in the sense of not mutually attainable. Experience may well teach us that we cannot have our cake *and* eat it, but it does not alone dictate which of the exclusive disjuncts we must pursue. Thus we can expect that the realist may attempt to salvage his pet cognitive aim for science by a Duhem-Quine type move against an axiological falsificationist who claims the realist's aim has been "refuted."[5] In this way a naturalistic axiology allows an opening to the essentialist defense against relativism, for one can concede a good deal to the historicist by allowing that epistemic aims at the periphery of the web of values are negotiable under the demands of experience, but still cling to some core epistemic aims (such as knowledge of an observer independent reality) as non-negotiable against any upheaval in the remainder of our beliefs.

However, as is well known, Laudan is no friend of realism. Focusing on the role of *truth* as the realist's ultimate aim, Laudan argues that to be a goal of rational inquiry a goal must motivate inquiry such that it is possible to know either when the goal is attained or that one is approaching closer to that goal. "Truth" on the traditional correspondence account satisfies no such conditions. In accord with his naturalism, Laudan does not reject "truth" as a motivating goal on account of the *internal* problems of the correspondence theory, but on an allegedly empirically discovered constraint imposed by the way the world is. Presumably the world could have been different. We could have been beings with intuitive faculties of truth-detection; indeed if truth had unconditional survival value, we might expect the evolutionary process to have bred us with such a faculty. But what we have discovered -witness the history of scientific change- is that in fact we have no such faculty, nor can we infer attainment or even approach to the truth about an observer independent world from any faculty we do have. So for the rational scientific inquirer, truth can have no motive power. The axiological naturalist regards realism as a contingent thesis about the aim of science, and it is one which the history of science has shown to be "utopian" in the pejorative sense of unattainable, or at least such that we cannot tell if we have successfully attained it or not (Laudan (1984), pp.51-53).

2. The Bohr-Einstein Debate

The Bohr-Einstein debate on the acceptability of quantum mechanics is a particularly obvious case of axiological upheaval because of the very long-standingness and fundamental nature of the aims being debated. I turn now to use Laudan's model of scientific change as a way of enlightening what is going on in that obscure chapter of recent physics, as well as to discern how that enlightenment might reflect back on Laudan's model.

2.1 Axiological Ascent

First consider Laudan's fundamental point that when consensus on theory acceptance cannot be achieved by appeal to methodological directives, we should expect to see "axiological ascent." In the Bohr-Einstein case we do in fact find a move from a discussion of quantum theory itself to a discussion of what constitutes an acceptable description of basic physical processes. And we do find that Bohr and Einstein have very distinct -and it would appear incompatible- aims in this respect. What we do not find, however, is the participants debating the rationality of the aims they each accept. Each participant sees his opponent's aims as essentially tantamount to having abandoned "doing physics" at all. Einstein complained in a letter to Schrödinger on 31 May 1928 that the Copenhagen point of view is a "tranquilizing philosophy" which "for the time being, provides a gentle pillow for the true believer" (Prizbaum (1967), p. 31); while Bohr confided to Rosenfeld his grief over his conclusion that "'Einstein had left physics';that was how he expressed it. Einstein had abandoned physics after 1920."(Rosenfeld (1963), transcript p. 14) Thus each side saw the aims it was defending as constitutive of doing science, but since neither rose to debating the rationality of selecting their differing aims, no resolution could be reached.

The general obscurity over what is at stake in the interchange is made all that much murkier by the attempt to restage this conflict on the philosophers' battle plain of realism versus anti-realism. All sides see Einstein defending some sort of realism, so it is natural to suppose that Bohr must be opposing it, at least as long as the label "realism" is left unanalyzed. Admittedly a great deal of what Bohr says concerning the abstract status of particle and wave "pictures" is in perfect harmony with what one would expect from an anti-realist. Thus in the Popperian presentation which echoes throughout the literature we are to see Einstein as the lonely guard of the realist citadel besieged by the anti-realist rabble of the gang of Copenhagen who have been stirred up by positivist-instrumentalist propaganda.

But this story won't bear up to scrutiny.[6] First, unlike the positivists, Bohr's claims about classical mechanical pictures have nothing to do with straightforwardly epistemological issues, but are based on the news of an empirical discovery of a contingent fact: at the microlevel interactions take place discontinuously in the phase space of possible classical mechanical states. Second, Bohr makes clear that in an uncompromising sense he is an *ontological* realist about the existence of atoms:

> Quite apart from the fundamental question of whether we are justified in demanding visualizable pictures in fields which lie outside of the reach of our senses, the atomic theory was originally of necessity of a hypothetical character. However...the limit of possible observations has continually been shifted...the extraordinary development in the methods of experimental physics has made

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known to us a large number of phenomena which in a direct way inform us of the motions of atoms and of their number. ...However, at the same time as every doubt regarding the reality of atoms has been removed and as we have gained a detailed knowledge of the inner structure of atoms, we have been reminded in an instructive manner of the natural limitations of our forms of perception." Bohr (1934), pp. 102-103.

The last sentence of this passage could hardly be attributed to an "anti-realist." Bohr clearly believes a) the ontological thesis that atomic systems are real, and b) that quantum physics provides "detailed knowledge" about them. Complementarity does not intend to controvert either of these theses; what Bohr wants to teach is the "epistemological lesson" that the classical concepts, derived from "our forms of perception," are "limited" by what we have learned about nature. That limitation reveals that where the effect of the quantum of action is significant, we cannot picture microsystems in well defined classical mechanical states independently of their interactions with observing instruments. Insofar as the *classical* realist's goal employed such concepts, *nature* has taught us *that* goal must be refashioned. One could not ask or a clearer exhibit of the outlook of naturalistic, axiological *realism.*

The ontological question of the *reality* of the systems which quantum mechanics describes is not at issue in the discussion between Bohr and Einstein, but what is in dispute is what constitutes an *acceptable description* of such entities. In fact the preferred idiom of the Bohr-Einstein discussions neglected the realist/anti-realist discussion of "truth" and "reality" and was expressed in terms of "objectivity." The classical *standards* for an objective description defended by Einstein clashed sharply with the new standards for an acceptable description advocated by the "quanticists." We have here, then, the makings for a first class application of the Laudanian schema for understanding change in scientific belief at the axiological level.

2.2 The Character of the Debate

In the first stage of the debate Einstein tried to find some (*Gedankenexperiment*ally conceivable) empirical evidence which would beat the limitations of the indeterminacy relations, thus showing the *empirical inadequacy* of the theory. In the two Solvay exchanges of 1927 and 1930 Bohr heroically repulsed the Einsteinian assault by showing that the phenomena which Einstein sought could not in fact occur because they required physically impossible experimental arrangements -a diaphragm or a photon box which was at once both fixed and movable.

In the second stage the disputants *ascend* to defending incompatible standards of acceptable description. In the EPR argument Einstein judges the quantum description to be "incomplete" because of its failure to determine the value of a physical quantity which was accorded "an element of physical reality" even though, by the physical conditions of the experiment, no *empirical* determination of the values of both the relevant quantities is possible. Thus it was not *empirical* reality which outstripped the resources of the theory, but an *unobserved* quantity which was to be accorded an element of physical reality because its value could be determined with 100% certainty due to an observation made on *another* system which had formerly interacted with it. So, since we have a free choice and could have measured the unobserved quantity, and since the system in question is by now spatially separated from its former partner, the quantity in question must in some sense "be there" to be measured should we have chosen to do so, even though the decision to measure its complementary observable requires that we do not in fact exercise that choice. To play on a Kantian vocabulary, we could say that Einstein now found the theory empirically adequate but *transcendentally inadequate*.[7]

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Essential to EPR's reasoning was the assumption that "no reasonable theory could be expected to deny" that the spatially separated systems of the formerly interacting pair existed in separate mechanical states that could causally affect each other only under the constraints imposed by relativistic locality. Recent work has shown quite convincingly that it is this *separability* assumption, rather than determinism, or even locality as such, which Einstein defends against the quantum revolution (Howard (1985), (1989), and Fine (1986)). Einstein's commitment to separability is a function of its closeness to basic aims in the mechanical description of nature, as can be seen in his letter to Born:

> ...if one renounces the assumption that what is present in different parts of space has an independent, real existence, then I do not at all see what physics is supposed to describe. For what is thought to be a 'system' is, after all, just conventional, and I do not see how one is to divide up the world objectively so that one can make statements about the parts. Born (1969), pp. 223-224; as translated and cited by Howard (1985), p. 191.

Classical physics had learned to construct "objective" descriptions of an observer-independent physical world in which the detachment from the observer necessary for objectivity is guaranteed by the fact that the system being described is in no dynamical interaction with the "observing system." A physical system which is thus mechanically isolated from the observing system can be described as a well-defined object because it can be ascribed a determinate mechanical state isolated from interaction with the state of the observing system. Classically this descriptive aim was justified as attainable by assuming separability, thereby guaranteeing that spatially separated systems exist in separate real states that can affect each other only through local causal influences. Thus Einstein's position can be captured in the hypothetical imperative: if science's goal is an *objective* description of the physical systems which are the components of the whole physical universe, these systems must be individuated according to the principle of separability. Abandonment of separability is *rational* only if one abandons the goal of objective description.

Although Bohr disputed the ontological move which accorded an element of physical reality to the unobserved quantity in the EPR arrangement, surely if we assume that the classical mechanical state defining concepts refer to properties objectively possessed by entities which observation in no indeterminate way affects, then the inference from the observed to the unobserved seems well-founded, or at least plausible. But Bohr undoubtedly did deny this inference, and he did so for a reason which must warm any naturalist's heart, an empirical discovery unearthed in the progress of science: the quantization of action expressed in what he repeatedly called the "quantum *postulate*." This expression signals Bohr's conviction that nature had dealt the physicist a new surprise about herself: at the atomic level interactions between systems simply do not take place as a continuous spatio-temporal and dynamically-conservative process as the classical mechanical scheme presupposed. Physics has discovered a surprising constraint on how we can describe the world; we cannot achieve the classical aim of "picturing" interactions between systems -at least on the micro-level- in terms of a continuous change of state in which separable interacting systems each retain well-defined mechanical states. Thus we cannot read realistically the mini-mechanical models we make of the careers of particles and waves over the time between preparation and detection as they would "look" to a ghost spectator. Although the interpretation of an experimental interaction as an observation must make use of such classical models of particles or waves passing through slits and diaphragms, these are abstractions, not conceptual photographs of micro-reality as it really is when isolated from interaction with an observing system.[8] Thus what Bohr rejects is the classical correlation of *ontological* models of objects as they really are with the *mechanical* models physics constructs for their instrumental value in interpreting experimental phenomena.

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Einstein would surely defend his position by rejecting Bohr's reasoning from the phenomena to the claimed discovery of a fundamental discontinuity in physical processes, expressed by the quantum *postulate*, for it violates the aim which for Einstein took priority over accepting discontinuity at the microlevel, namely the goal of constructing an objective description of physical interactions. The priority of Einstein's aim is tied to his insistence that a description of an interaction between physical systems must individuate the systems by appeal to separability. Since separability enables one to distinguish the "parts" of a "whole" physical interaction, it is the key which enables the objective description of the object system as detached from the observing apparatus. Seen in this light Einstein's aims rationally justify his refusal to countenance Bohr's claims about the alleged "discovery" of a fundamental discontinuity at the microlevel. He can simply counter that Bohr only regards the quantum postulate as *axiomatic* because Bohr interprets the experimental evidence under the very theory whose completeness Einstein challenges. Have we come this far only to be left hanging with an incommensurabilist's standoff?

3. Realism and the Aim of an Objective Description of Nature

It is fair to say that that is where the debate did stand for a good thirty years or so. But now the sort of phenomena imagined by EPR are real experiments. The consensus conclusion emerging from the experimental confirmation of so-called Bell-phenomena as they appear in the Aspect experiments is to the effect that they refute the assumption of separability not by appealing to any prior acceptance of the quantum postulate (as Bohr was forced to do) but by the straightforward statistical analysis of the correlations between experimental outcomes made on subsystems which are space-like separated such that any communication between them would have to be superluminal (Cf. Cushing and McMullin (eds.) (1989)).

3.1 The Aim of Objectivity and the Laudanian Model

As we have seen above, Laudan's analysis leads us to see realism as a thesis about science at the axiological level. The realist sees the aim of science as extending beyond the prediction of phenomenal regularities to provide an *objective* account of what produces the phenomena to which the scientist points as the empirical evidence for the theory from which such an account is drawn.

Seen in this light it would appear that much of the recent discussion of realism versus anti-realism has been off the mark, including some of Laudan's own pre-1985 anti-realist polemics (*Cf.* Laudan (1981), revised as Chapter 5 of Laudan (1984)). Much of that discussion has been at the *epistemic* level in challenging the realist's rational justification for holding as approximately true beliefs about the unobservable entities postulated by successful theories. Typically, the *evidence for* such beliefs has been the alleged success of science and the cumulativity of its progress. In other words "realism" has been treated as a theory promulgated by *philosophers* seeking to explain the success of science, and it has been attacked as unconfirmed by the evidence adduced in its behalf. But if realism is seen as referring to an *axiological* commitment on the part of *scientists* regarding the aim of science, as Laudan emphasizes even while attacking its credentials as a philosophical theory explaining the success of science, then it seems misplaced to treat it as a theory explaining anything. In fact Laudan explicitly rules "intentional realism" out of bounds in his "confutation," but it is hard to understand how one can do this if the realist thesis is about the aim of science.[9]

Rather than expecting the realist to prove that only realism can explain the success of science, Laudan's current naturalistic axiology virtually demands that the anti-realist will demonstrate the irrationality of pursuing a realist aim by showing it to be unattainable. Assuming that the realist aim is to make justified true statements referring to unobservable processes that produce observed phenomena, then the axiological naturalistic anti-realist must argue that the realist's aim cannot motivate inquiry because what we have learned from nature is that we have no way of determining whether or not we are approaching the *true* account of such goings-on behind the phenomena; we cannot tell if the unobservable objects we describe behind the phenomenal screen correspond to any independent reality. Now if the Bohr-Einstein dispute is properly characterized as about realism in this philosopher's sense, we should expect to find the disputants discussing this issue, but do we?

Certainly not in any explicit manner. Each side takes it for granted that the other accepts that there really are physical systems which quantum mechanics aspires to describe (though Einstein is inclined to regard the reference as to ensembles of such systems, rather than as Bohr maintains, to them individually) -at least insofar as their behavior manifests itself in empirical phenomena- and that an acceptable theory should provide all the knowledge that is possible for humans to have about such physical systems at the microlevel.[10] On Einstein's definition of "objectivity," Bohr's insistence that it is impossible to define the state of the object system independently of the interaction with the observing system was tantamount to abandoning the aim of objective description. For his part, Bohr countered that the complementary description of all possible observing interactions exhausts all that can be known and all that is needed for an objective account -in his sense- of micro-systems. No more poignant evidence of this can be given than Bohr's sad comment the day before he died: "[The philosophers]...did not see that it was an objective description, and that *it was the only possible objective description.*" (Bohr (1962), p. 3; italics mine) So Both Bohr and Einstein insist that their rival views on the status of quantum mechanics each preserve "objective description" as the essential criterion for an acceptable description.

3.2 The Methodological Significance of the Bohr-Einstein Debate

Although both Bohr and Einstein appropriate the label "objective description" to refer to what they take to be an essential aim of science, the different meanings they give to this term, leads them to espouse different methodological injunctions for determining the acceptability of quantum mechanics. Einstein is relying on a methodological rule that if you aim to describe physical systems *objectively*, you must construct a description in which the observing subject is mechanically "detached" from the object. Since, for Einstein, "objective description" in this sense is the aim of physics, no "reasonable theory" could be expected to deny separability. Furthermore, the success of all previous mechanistic physics is testimony to the rationality of such an aim.

If we adhere to this conception of objectivity, the mechanical model defined by the mechanical state of the observer independent system can be taken as an *ontological* model of the world behind the phenomena. Einstein fully well realized that proving such a correspondence held was beyond the reach of empirical science, as critics of the correspondence theory have never tired of pointing out, but the fact that classical physics allowed constructing an ontological model of the observer independent world, tended to make the ability to construct such a model the motivating aim of a classical realist interpretation of science. For a devout believer in the ability of physics to construct such a model of an objective nature as it would look to a ghost spectator, mechanical separability was in effect an essential article of faith.

Bohr holds that an empirical discovery forces the abandonment of this aim, *not* because the discovery refutes the aim of *gaining knowledge* about the real systems which produce the phenomena that form the evidential basis of the quantum theory, but because the empirical discovery of the quantum postulate makes physically unattainable the determination of the classical mechanical state of a system isolated from the interaction necessary to observe it. This in turn makes it impossible to stake realist claims on the presumed "transcendental" correspondence between mechanical and ontological models. So the "objectivity" of a description can no longer refer to its ability to construct an ontological model of the object as it exists independently of its observational interaction with the observing system. Consequently, Bohr reappropriates the term "objective description" to refer to a description of the *whole phenomenon* of an observational interaction in terms which can be communicated *unambiguously* from one scientist to another (e.g. Bohr (1958), p. 74).

To summarize the axiological lesson of the Bohr-Einstein debate, we may say that the methodological imperative which permits Einstein to assume separability in describing the observational interactions is the consequent of the antecedent conception of "objectivity" which requires that the object system be described as existing in a well-defined classical mechanical state isolated from the observing system. Bohr can deny the consequent of the hypothetical imperative expressing this methodological rule only because he is prepared to deny the *antecedent aim* of describing nature objectively in this sense. Thus he can reject the principle of separability on which Einstein relies in setting up the EPR *Gedankenexperiment,* because he no longer shares Einstein's aim for a physical description of objects at the atomic level.

I suspect Bohr never had a fully self-conscious awareness of what we have called the "principle of separability" such that he could have thought of his differences with Einstein in this explicit way. In fact Bohr's notoriously obscure reply attacked the EPR argumentation on the grounds that the proposed reality criterion was "ambiguous," but why would the classical mechanical and dynamical concepts become "ambiguous" in reference to unobserved objects once action is quantized? The fact that we have a choice of which observation to make which is free of any constraints imposed by nature -other than that they are exclusive- and the tendency to think of observation as revealing the value of a pre-existing quantity -as classically it is indeed conceived- lead us to think that EPR refers to a *single* physical situation which could be observed in either of two (unfortunately exclusive) ways. But that is not what Bohr would allow, because for him the exclusive nature of the differing observational arrangements means that we choose to realize one of *two distinct phenomena*, and since distinct quantities are determined in these distinct phenomena we are justified in according physical reality to one or the other, but not both. Consequently Bohr never expresses his disagreement with Einstein in terms of separability but chooses the idiosyncratic term of "ambiguity" to express what is wrong with Einstein's criterion of reality, because it could refer to different phenomena depending on which way the *free choice* of the experimenter goes in realizing which of two possible phenomena to actually bring about.

Finally we must return to the original question of what light this story throws on the question of the selection of aims for scientific inquiry. At least in this case the axiological ascent which is essential to Laudan's account seems to have occurred. But Laudan, I take it, would infer from this case that what has been found wanting is the aim of realism; indeed that we have learned from nature that a realist aim for inquiry -at least in microphysics- is a physically unattainable end. But I do not see either side in the Bohr-Einstein conflict arguing against the truth of bare existential claims about atomic systems, and I see Bohr -the supposed anti-realist- as arguing mightily for the fact that quantum physics gives us a great deal of knowledge about individual atomic systems -even though that knowledge cannot be expressed by giving kinematic-dynamic careers of entities possessing properties corresponding to the old classical state defining parameters of the mechanistic description. Thus I would call the aim which seems to have been ruled out of bounds by the quantum revolution not the aim of realism *tout court*, but the aim of a particular kind of realism, one tied to Einstein's notion of objectivity and derived from the classical principle of separability, but not constitutive of the view either that unobserved entities exist or that we can have objective knowledge -in Bohr's sense- about them.

Of course Einstein's conception of objectivity had the attractive feature that it licensed the inference from an objective description in his sense to an ontological model of nature existing as entities possessing properties corresponding the to mechanical state parameters of an isolated physical system. This is a vision of reality which we can no longer accept if we accept the completeness of the quantum description. But one cannot infer from the failure of this classical model to extend to the microphysical level that no ontology consistent with the completeness of the quantum description of microsystems can be formulated. After all we should not expect physics to provide the premises from which a metaphysics can be *deduced*, but the awesome success of this theory can be a springboard to new ontological visions of the nature of physical reality. Moreover, the role of such models can hardly be despised, for it can hardly be doubted that the history of science gives some plausibility to the suggestion that such ontological models of nature which have been derived from the science of each era have been in some kind of dialectical interaction with the empirical, theoretical, methodological, and axiological progress made in the growth of human knowledge of the natural world.

Notes

[1]Work on this paper was made possible by an NEH Summer Seminar directed by Prof. Larry Laudan, June-July, 1989.

[2]The story Laudan tells in (1984), pp. 56-61 can be considered a case in point.

[3]This is Laudan's reply to the criticism that while "secondary" aims may change, science has always had the one "primary" essential goal of "Knowledge"; *cf.*, Laudan (forthcoming).

[4]Indeed, Laudan points out that his scheme invites us to examine the history of science to determine the "dynamics of cognitive value change."(1984), p. 139) With fellow collaborators he has already made steps in this direction (Laudan, Laudan, and Donovon (1988) and Laudan *et al.* (1986); for some critical comments on this procedure, *cf.* Cushing (1989).

[5]*Cf.* McMullin (1988) for a survey of the spectrum of axiological positions, from an extreme relativism to a strong essentialism.

[6]I have defended this *realist* interpretation of Bohr's philosophy more extensively elsewhere; *cf.* Folse (1985, 1986a,b, 1987, and 1989).

[7]Actually at one point Laudan refers to unattainable goals as "transcendental." (Laudan (1987a), p. 30, n.18).

[8]Consequently, after EPR, Bohr's defense of his interpretation ever more emphasized the holistic character of the observational interaction as a single indivisible phenomenon, *cf.* Bohr (1958).

[9]*Cf.* Laudan (1984), p. 105. Of course if one is inclined to allow for a good deal of "sleepwalking" on the part of individual scientists, then one might allow their intentions are irrelevant to the aim of science itself. That may be, but then the problem arises of explaining how such disparate and diverse intentions of human scientists

have been so successful at achieving the presumed aim of science which forms no part of their intentions.

[10]As has been frequently observed by scientists who watch philosophers doing battle over "realism," scientists are not so likely to talk about "truth" and "reality," when debating the acceptability of a theory. Indeed the contemporary breed of realists are well-advised in shying away from speaking of realism in terms of "truth," "correspondence," and "reference" (*e.g.*, Hacking (1983)).

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