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CHAPTER SEVEN

The Philosophical Differences Between Heisenberg and Bohr

The terms "reality," "descriptive concept," and "observability" had different meanings at this time for Bohr than they had for Heisenberg, indicative of deep philosophical differences.[1] Bohr was of the type of a Faraday grounded in imaginatively intuitive common sense. Heisenberg was more of the type of a Maxwell or an Einstein, exploiting mathematical structures that were imaginatively unintuitive [*unanschaulich*] to common sense in order to uncover new and hitherto unsuspected structures in nature. Bohr and Heisenberg were by basic temperament, and at this time explicitly, moved by incompatible philosophical values.[2]

For Heisenberg, at the start of his career in 1925, the mathematical formalism entered essentially into the definition of a physical concept. A physical concept for him was defined by implicit definition through the interpretation of those

1 The role of metaphysics as a heuristic for science is stressed by M. Wartofsky, and others. See, for example, his "Metaphysics as a Heuristic for Science" in *Boston Studies in the Philosophy of Science*, III (New York: Humanities Press, 1968) (eds.) R. S. Cohen and M. Wartofsky, 123–72. The most powerful philosophical critique of the reduction of natural science to mathematical models is E. Husserl's *Crisis of European Philosophy and Transcendental Phenomenology, op. cit*.

2 Interesting in this connection are Heisenberg's reflections contained in an interview on 25 February 1963, AHQP, Heisenberg-Kuhn; also his published recollections "*Erinnerungen …*" TPTC, *op. cit*.

mathematical relations which the theory established between its own primitive terms. The domain of the physically observable, and consequently of the physically and descriptively real was then outlined by and through the interpretation of a mathematical theory. Here Heisenberg was reflecting his interest in Hilbert's axiomatization of geometry.[3] The notion of implicit definition was also used by Einstein and Weyl in their treatment of the kinematical concepts of relativity mechanics and the notion must have been well-known at Göttingen when Heisenberg was there. Following Einstein, Heisenberg held that implicit definition played the determining role in specifying what could or could not be observed and described, and hence what was or was not real.

Besides implicit definition, there is another element necessary to define the usage of a physical concept, this is the *ostensive* or *operational description* in the pre-theoretical language L_P of the situations in which the *theoretical primitives* of the physical system occur in an identifiable way. Consider for example, the case of *force*. Force is exemplified in a stretched spring, of which a description in pre-theoretical language L_P is, viz., "A stretched spring exemplifies force (as sensed by muscular effort)." Force, however, is also a theoretically defined quantity in L_N linked by Newton's Laws of dynamics and to Hooke's Law for a stretched spring. This latter role uses measure numbers in its description, viz., "The Newtonian force in the stretched spring is 10 kgs."

At this point, convention may—and in fact does—step in, clearly and decisively. It is an empirical fact of our culture that regularly and for the most part, the term "force" has come to mean (in non-relativistic cases) whatever obeys Newton's Laws for force. This is the linguistic norm prescribed by convention in our culture. It is based upon the assumption that Newton's Laws have sufficient empirical warrant. It is neither given immediately by experience, nor is it an a priori condition of experience or language—except to the extent that in conventional contexts we are bound by the conventions of our time and situation. Conventions, however, are decisions between possible alternatives; at another time for another community, the term "force" could mean, for example, that which is exemplified in the stretching of a spring whether or not Newton's Laws were fulfilled.

So the question arises: what is the relation between linguistic conventions and descriptive ontology? Does a description which is correct by conventional linguistic standards also stand correct by the standards required to provide an ontological description of nature? There are many who would hold that this is so and that the philosophy of nature is nothing more than a systematization of what is implicit

3 D. Hilbert, *Grundlagen der Geometrie* (Leipzig: Teubner, 1899), translated under the title *The Foundations of Geometry* (Chicago: Open Court, 1902).

in the linguistic conventions of particular communities at particular times. The philosophy of nature then becomes part of the history of ideas and the sociology of knowledge.

The reduction of the philosophy of nature to a socio-empirical discipline is, however, contrary to the Western philosophical tradition which has always considered them to be distinct. This tradition seeks to be normative for all places, times, and cultures; it deals not just with what is said to be the case but with how this should be described and lived to express the universal philosophical values of that tradition. These values are grounded in the belief that human life and experience have a common meaning and a common goal that is universal for the human species and that is rational, practical, and transcendental to individuals, societies, histories, and cultures. The philosophical tradition in the West began with the Greek philosophers of the sixth century B. C. E. To what extent did the young Heisenberg share these values?

Heisenberg loved the Greek classics and the classical music of Bach, Beethoven, and Schubert. He recounts that in the Spring of 1919 during the brief "Soviet" take-over of Bavaria and while he was serving briefly in the opposing Cavalry Rifle Division No. 10, he spent his off-duty hours on a rooftop reading the dialogues of Plato and while on duty around the lake of Starnberg he enjoyed discussing the nature of atoms.[4] In 1922–23, he went to the University of Göttingen to write his doctoral dissertation. Here the memory and philosophy of Edmund Husserl was strong throughout the departments of mathematics and natural science. He later became a friend and frequent visitor of Martin Heidegger, Husserl's student and Husserl's successor at the University of Freiburg-im-Breisgau. He wrote an essay for Heidegger's *Festschrift* on the significance of the quantum Uncertainty Principle.[5] Though most deeply attracted to Greek philosophy, and especially to the philosophy of Plato, he would have been familiar with the cultural critique of the materialism of modern science by Heidegger and Husserl.[6]

The roots of this critique, of course, go back to Heraclitus in the 6th century BCE who "mocked" the images and statues of the gods, but "reverenced" the gods

4 Cf, W. Heisenberg, *Der Teil und das Ganze* (1969), trans. as *Physics and Beyond* (1971).

5 W. Heisenberg, "*Grundlegende Voraussetzungen in der Physik der Elementarteilchen*," in *Martin Heidegger zum siebzigsten Geburtstag: Festschrift* (Pfullingen: Neske, 1959), 291–297.

6 E. Husserl's *Die Krisis der europäischen Wissenschaften und transzendentale Phänomenologie* was posthumously published in 1954; in this late work Husserl criticized the "teleology of Western culture" as having replaced reverence for "Being" with the search for "rational scientific explanation" as if this were the *Gesamt- und Grundwissenschaft* ("total and basic science"); such also was Heidegger's critique. Neither, however, deplored modern science; they deplored just its cultural misuse.

they represented, for, as he said, the gods were their "soul." To take a "rational scientific stance" towards nature is to make (mathematical) images of nature and to risk the denial of nature's "soul"—the human meanings that inhabit those very human images. Yet, what has characterized Western culture is the search for the illusory goal of *Gesamt- und Grundwissenschaft,* that is, of *total and basic science*. It could be said of both Husserl and Heidegger—and also eventually of Heisenberg—that, though mathematically trained, each came to recognize the illusory nature of this goal and in their own way came to "mock" the mathematical images and scientific representations of nature in order to show "reverence" for nature's "soul."

Certain features about the two thousand years of search for perfect scientific knowledge in the West are relevant to our present consideration because of the shock generated in the scientific community by relativity—special and general—and the quantum theory. In the first place, at the start of this trajectory, two roads were distinguished: Parmenides spoke of the Way of Opinion and of the Way of Reason. The Way of Opinion[7] followed the intuition of the senses, risking the danger of being carried along by the never-ceasing flow of sense experience into a world without constancies and invariances. The Way of Reason,[8] however, judged not by what seemed to be, but by the stable unchanging (generally mathematical) aspect of things which only Reason attained. This carried with it the danger of denying reality to secondary qualities and to real change in the natural world. The Way of Opinion was followed by Aristotle, Aquinas, Hume and the empiricist tradition. Among its representatives would be counted scientists of the Baconian inductive tradition, Darwin for example, Faraday and, to a large extent, Bohr. The Way of Reason[9] was followed by the Pythagoreans, Plato, Archimedes, Descartes,

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7 Among contemporary authors, T. S. Kuhn and Agassi, for example, come close to identifying the philosophy of science with the sociology of knowledge. M. Wartofsky articulates a position which the present author finds more agreeable, in "Metaphysics as a Heuristic for Science" in *Boston Studies in the Philosophy of Science,* vol. III, *op. cit*. It is a position consecrated by the studies of P. Duhem, A. Koyré, A. Crombie, and others.

8 Wartofsky writes: "The representation of the structure of science is a model (an interpretation, a mapping) of a more general and abstract theory of structure, which I take a metaphysical system to be … Then the history of alternative metaphysical systems reveals itself as a rich heritage of *theories of structure* in which the essential features of theoretical construction are set forth in the most general way": in his "Metaphysics as a Heuristic for Science" in *Boston Studies*, vol. III, *op. cit*., 152.

9 For studies of the influence that the Aristotelian and Platonic traditions had in the development of modern science, consult the classic work of P. Duhem, *Etudes sur Leonardo da Vinci* (Paris: Hermann, 1906–13), and various essays in the collections, *Towards Modern Science,* vol. I, ed. by R. M. Palter (New York: Noonday Press, 1961), *Scientific Change*,

and the rationalist tradition. Among its representatives would be counted scientists in the Archimedean or Platonic tradition, such as Galileo, Newton, Maxwell, Einstein, to which Heisenberg was drawn.[10]

In the second place, it became gradually clear that the ideal of perfect scientific knowledge could not be fulfilled in its original sense.[11] Looking back over the course of Western philosophy and science—and for most of its period philosophy was Western culture's attempt to reach perfect science—one sees that the first condition for perfect scientific knowledge, the necessity of a universal object, was the harmony exhibited by the universe. This led to the question: What binds all things together into an ordered, moving totality in which things come and go, in which men are born and men die, and in which the cycle of the seasons keeps pace with the yearly procession of the planets along the highway of the celestial zodiac? Whatever this is, it is the unifying element of the cosmos. For Aristotle it was the kind of teleological causality that accounted for the universal fact of motion. For Newton, it took the form of mathematical laws that governed the patterns of motion in a *containing* Euclidean space. Up to the time of Kant, it was possible to speak in objectivist language of unifying principles unrelated to the human spectators of the cosmic drama. With Kant,[12] however, the view of the human subject as a spectator of nature was supplanted by the view that in some sense the human subject constitutes the universal forms under which nature presents itself. The Kantian view attacks the scientific ideal, it denies that perfect science is capable of revealing nature independently of human presence and activity in nature. From the time of Kant on, science had to be open to the possibility that natural science depended on an active subject/object relationship and took the form of

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ed. by A. C. Crombie (New York: 1963). For the Aristotelian or empiricist influence, see, for example, J. H. Randall, Jn. *The School of Padua* (Padova: 1961), A. C. Crombie, *Robert Grosseteste and the Origins Of Experimental Science, 1100–1700* (Oxford: Oxford Univ. Press, 1953); L. Geymonat, *Galileo Galilei* (New York: McGraw-Hill, 1965), E. McMullin, "Empiricism and the Scientific Revolution," in *Art, Science and History in the Renaissance*, ed. by C. Singleton (Baltimore: The Johns Hopkins Press, 1968), 331–69.

10 There have been many studies on the Platonic *influence* in the development of modern science. Besides the works listed in the note above, see, for example, E. A. Burtt, *The Metaphysical Foundations of Modern Physical Science* (London: Routledge and Kegan Paul, rev. ed. 1931), A. Koyré, *Etudes galiléennes* (Paris: Hermann, 1939), A. Meier, *Die Vorläufer Galileis im vierzehnten Jahrhundert* (Rome: 1949), A. Crombie, *From Augustine to Galileo* (Cambridge, Mass.: Harvard Univ. Press, 1953).

11 P. A. Heelan, "The Search for Perfect Science in the West," *Thought*, 43 (1968), 165–86.

12 Cf. I. Kant, *Critique of Pure Reason*, B xiii (p. 20 in N. Kemp Smith's translation).

an interrogative dialogue between human interrogators and nature's responses to human questioning.[13]

It has then to be taken as evident that humans themselves are one of the sources that contribute to the outcomes of dialogues with nature. But how do we define what this contribution from human sources is, and where it comes from? One source, of course, is the experimental practices and protocols by which humans interrogate nature in the protected environment of the laboratory. But how does nature respond? Heraclitus said that nature loves to hide! Does nature from its side interrogate humans? Is measurement a two-way interrogation? If not, then science would be a human monologue! If so, then science ought to be a rational collaboration with nature rather than what has often been described as a way to "subjugate" nature as if nature were an enemy or a reluctant native tribe. Collaboration would replace objectivity, and scientists would see themselves more as custodians and gardeners of nature than as conquerors of reluctant native tribes.

From the time of Kant on, it began to appear that the notion of a perfectly objectifiable cosmological science was a chimera. The human subject was recognized to be the active interrogator in a dialogue between humans and nature. Humans for their part only ask questions relevant to human interests; nature answers intelligibly only when its interests are involved. Human questions are translated into research methods capable of eliciting meaningful responses from nature. Such an active orientation of a searching and inquiring human subject toward a responsive horizon of nature is what is called by Husserl an "intentionality structure." It is the embodied mental engagement that gives an intelligible unity to a linguistic framework. A linguistic framework is the externalization of a common intentionality-structure in a community of common discourse.

Bohr and Heisenberg exemplified at this time two different models of rational thinking, each well represented in the Western tradition.[14] Heisenberg, on the one hand, represented the Archimedean-Platonic tradition.[15] Bohr represented a pragmatic "common sense" combination of the Kantian tradition and the empiricist-inductivist tradition; for him communication with colleagues would not be well served by insisting on a definitive philosophical discourse; instead he championed everyday—ordinary—language, L_O. Heisenberg disagreed; he believed that

13 P. A. Heelan, "Scientific Objectivity and Framework Transpositions," *Philosophical Studie*s (Dublin), 19 (1970): 55–70.

14 For more thorough treatment of the differences between Bohr and Heisenberg, see P. A. Heelan, *Quantum Mechanics and Objectivity, op. cit.*, and P. K. Feyerabend "The Recent Critique of Complementarity, I and II," *Philos. of Science*, 35 (1968): 309–31and 36 (1969): 82–105.

15 AHQP, Heisenberg-Kuhn, 11 February 1963; CDQP, 176–9.

the ontology of nature would not be well served unless the physical terms were taken to be defined implicitly by the mathematics of the physical theory. In this he agreed with Einstein's position on relativity physics. He advocated therefore a new descriptive kinematical and dynamical language for quantum physics that would reflect its new mathematical formalism. For him this new language would replace both L_N and L_P, because for him the ontology of nature would not be well served by these modes of discourse, although he agreed that there was a useful and, perhaps, even necessary place for them, in designating the domain of appearances to which quantum mechanical concepts applied.

Heisenberg did not at first question the possibility that science would discover in due time descriptive—even measurable—concepts of a non-classical kind. Such a descriptive concept would be exemplified in quantum data, the outcome of quantum measuring processes. A quantum datum event would be signified by the occurrence of a classically describable signal (e.g., a pointer reading, photographic record, etc.), but the description of the quantum datum entity made present by the measurement would not be made in classical terms but in a future non-classical L_Q. The non-classical kinematical and dynamical properties would be defined by implicit definition within the hermeneutical circle of a non-classical kinematical and dynamical theory. *In the abstract sense of "observability" with which Heisenberg started, that is, in the sense we have called "E-observability," these non-classical quantities would be observable and endorsed as part of the descriptive ontology of nature in non-classical* L_Q.

Bohr, however, belonged to a different rational tradition. He was given more to *intuitive reasoning*, and working with a *paradigm* to get a *feel* for the physics of the case, and using mathematical formulations only as convenient tools to express imperfectly the content of his intuition. Physical reality for him was not circumscribed by an interpreted mathematical theory: it was revealed in a vague intuitively grasped way wherever and whenever people communicated with one another, even before the concepts were put into mathematical form. Influenced by the thought of William James, he took words to be mysteriously evocative of a great deal more than could be mathematized.[16] For Bohr, everyday language L_O was the sole bearer of descriptive ontology. The language of classical physics, L_N, was for him an idealization of L_O. L_O was an important instrument to refine, generalize, objectify, and to bring under predictive control large areas of the rich but vague domain of what everyday language described. But whatever ontological status L_N enjoyed, it borrowed it from L_O.

16 Mario Bunge would call this "direct observability," *Scientific Research II, op. cit*., 162.

A consequence of his basic philosophical standpoint was a more restrictive use of the terms, such as "reality," "descriptive concept," and "observation." I have already noted that *reality* for Bohr was *the objective content of what ordinary language* L_O *described or of its refinement in classical physical language* L_N. Descriptive concepts for Bohr were to be found solely in L_O or L_N. That there might be descriptive concepts yet to be discovered which were not of a classical character was ruled out by his philosophy. Finally, "to observe" meant for him "to register an event describable in the descriptive predicates of L_O or L_N and localized in a space-time neighborhood." Let us call the sense of *observability* derived from the latter meaning, "B-observability." The Principle of B-observability would then sanction as "real" only those states of affairs that were localizable and describable in ordinary language or in the descriptive language of classical physics.

Heisenberg relates that he and Bohr during the early part of 1927 disagreed over the proper use and interpretation of the two forms of the quantum theory—matrix mechanics and wave mechanics.[17] Schrödinger had persuaded Bohr during a meeting at Copenhagen that wave mechanics was at least as useful as matrix mechanics for dealing with quantum phenomena and Bohr became convinced that an adequate quantum theory had to include both in one system. By February 1927 he believed he had the solution to the paradigm problem, and also to the philosophical problem, in the new concept *complementarity*. It was not necessary, he thought, to invoke allegedly new kinematical concepts: it was sufficient to learn to restrict suitably the domains of applicability of the old concepts. This involved a new kind of logic, based on an epistemology of *mutually exclusive (i.e., 'complementary') ways of using descriptive statements* in a language; he called this usage "complementarity." He opposed Heisenberg's view then that new descriptive kinematical/dynamical concepts were required. Whatever can be described, can be described, he held, in everyday language L_O or in L_N. What was needed was a new way of using predicates that were complementary; it introduced into logic (really, epistemology) conditions under which a particular classical concept could be used and when it could not be used. Complementarity, then, was a strategy to preserve the old language but to use it systematically in a new way. By Spring 1927, Bohr had succeeded in persuading Heisenberg that complementarity was the correct solution.[18] "What was born in Copenhagen in 1927," Heisenberg wrote some years later, "was not only an unambiguous prescription for the interpretation

17 Heisenberg, "*Erinnerungen …*" TPTC, *op. cit.*; also AHQP, Heisenberg-Kuhn, 11 and 25 February 1963.

18 AHQP, Heisenberg-Kuhn, 25 February 1963.

of experiment but also a language in which one spoke about Nature on the atomic scale and, insofar, a part a philosophy."[19]

In spite of the opposition of some notable physicists, among whom were Einstein and Planck, complementarity, or the Copenhagen interpretation as it was also called, very quickly established itself in the scientific community. The Fifth Solvay Conference in the autumn of 1927 was the occasion for a major confrontation between Bohr and the antagonists of complementarity, especially Einstein. While Einstein was not then or ever convinced that complementarity was the correct path for quantum physics to take, he admitted he could not find a flaw in Bohr's logic. Heisenberg recounts that by the end of 1927, it began to be said everywhere that those people in Copenhagen seemed by all accounts to have an impregnable position and from that time on, he says, the burden of proof lay with those who disagreed with them.[20]

19 W. Heisenberg, "The Development of the Interpretation of the Quantum Theory" in NBDP, 15.

20 AHQP, Heisenberg-Kuhn, 28 February 1963.