Chapter 6
Bohm's Philosophy as Revealed by the Letters

The letters demonstrate that Bohm was exceptional for a physicist in that he took his philosophy very seriously.[1] More than that, he is even prepared to develop his own original philosophical ideas. One can attempt to divorce his scientific achievements from his philosophical approach, as do the Bohmian Mechanics group, but only if one ignores the actual development of his ideas as revealed in these letters.

Bohm based his philosophy on Marx and Engels, but their ideas had been interpreted by their followers, especially by Russian Marxists, such as Lenin. Thus Lenin's ideas were clearly an influence on Bohm, as we shall see. Additionally, there was a further important development of serious philosophical study and debate in the USSR in the 1920s, after the 1917 revolution. After 1930, Stalin took a personal interest in philosophy, suppressed all debate and banished all material from the 1920s so that he could present himself as the direct heir to Lenin in philosophical leadership (see Tucker 1990, Chap. 7). As a result, a debased form of philosophy was imposed under Stalin and exported to the Communist Parties of the world. This background is important in understanding Bohm, and we will return to it in Chap. 12 on Soviet Physics and Philosophy.[2] In discussing Marxism with his physicist friends in the 1940s, although his politics remained at a crude Stalinist level, as we shall see below, Bohm's philosophy linked up with the ideas of Marx and Engels while providing a framework to his attempt to deal with quantum mechanics. He would probably have

[1] See his letter admonishing Melba for ignoring philosophical questions (18, **45**, pp. 167–169). He argues that "[a]lmost no great physicist worked entirely without a philosophy", whereas today all physicists "want are "results" that "pay off" immediately in higher jobs, recognition, job security, navy contracts, etc.". Note also his comment to Miriam: "But I am afraid that my first love is the philosophical problem and not the detailed dry scientific problems. Yet it is the latter which supply the means by which the philosophical point of view comes close to reality and demonstrates its fruitfulness." (27, **104**, p. 344).

[2] In a 1953 letter, Bohm clearly shows some awareness of the "mechanical" approach of the Soviets, see (26, **97**, p. 320).

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read some of Engels' pamphlets, and we know he read the notes written by Engels on philosophy and science in *Dialectics of Nature*[3] in Portuguese,[4] so presumably he was familiar enough with the English version. In his interview with Wilkins[5] he noted that with his friend Weinberg in the 1940s "we were discussing on a rather superficial level, but even that level was enough to give overtones that were enough to arouse my energy."

We can assume that the "overtones" related, at least to some extent, to the distinctive ontology, or theory about the "stuff of the world" developed by Marx and Engels. This is a difficult subject, and its exposition is based on scattered parts of Marx and Engels' fifty-volume collection of writings, most of which are about their chief concerns with economics and politics. Also, much of their work, especially from the earlier formative period, was not available in English at the time of these letters. Here I would recommend the books of Allen Wood[6] and Scott Meikle[7] for far more complete expositions than the sketch I can give here. The first author is not a Marxist, but offers the sympathetic account of an expert on classical German philosophy; the second author is a Marxist, and unfortunately writes in the disputative style of left-wing groups, but has the distinct advantage of being an expert on Aristotle. Both authors would agree that Marx supports an ontology that is materialist. Wood takes the basic tenet of Marx's materialism to be *Naturalism*, which "says that the sole reality is the natural world, and this world is made up solely of matter." Naturalists, "deny that the world was created by anything outside it, and that natural motion requires God (or any other supernatural agency) as its cause". Naturalism thus defined implies realism, namely the "thesis that material things are not dependent for their existence or nature on any mind or minds."[8] Bohm is not usually very precise, but we may assume he was a materialist of this type in the period covered by the letters.

Marx's ontology, and Bohm seems to have agreed with this, in some sense, for most of his life, is also "organicist" or "essentialist". The world is made up of things or entities that have "qualities", that are not unchanging but have self-movement and internal tendencies, and that display novelty, coming into being and passing away. Both Wood and Meikle regard the entities of this philosophy as "goal directed" or "teleogical". They insist that the latter term need not mean, as critics suggest, directed by a "higher" power, or that the future can somehow cause the past. Aristotle used the term "final cause", distinguishing the tendencies in organic entities from "efficient causes", i.e. the usual causes in the natural sciences. Both authors see no fundamental conflict between efficient and final cause explanations, they may in

[3] Marx and Engels (1988).

[4] (20, **57**, p. 201).

[5] Wilkins (1986), Vol III.

[6] Wood (2004).

[7] Meikle (1985).

[8] See Wood (2004), Chaps. 7, 8, 11 and 12, for a fuller explanation, as well as a refutation of the post-war academic trend wishing to deny Marx's materialism.

fact be deemed to be complementary,[9] but see below for the problem of "mechanistic" ontologies. Both authors wish to treat Aristotle seriously, despite the tendency, since the 17th century Enlightenment, to denigrate him by identifying his philosophy with Scholastic interpretations of his work developed in the Middle Ages.

Such a "teleological" approach as referred to above has been widespread in evolutionary biology, though not without controversy.[10] Marx and Engels themselves used such an organicist approach in their analysis of society, which later became known as "historical materialism". The same approach was also deployed by Marx for economics in his *Capital*. Working within the German philosophical tradition, especially that of Hegel, Marx and Engels considered that social and economic entities developed in a "dialectical" manner. In simple terms,[11] this means such entities contained opposing forces, also known as "contradictions", which could lead to their transformation into something new. Unlike some of their followers, they only used this approach with subject matter in which they were very knowledgeable—Marx spent 25 years studying economic theories and data. As they point out several times in their polemics, nothing is easier than using dialectics as sophistry, something we will find Bohm guilty of in Chap. 11 on politics.

There is, generally, a problem of emphasis in interpreting Marx and Engels on the question of "mechanism"[12] or a "mechanistic philosophy": the approach which says the world can be reduced to basic entities or "simples" which are fixed, or changing only quantitatively, normally using causality in the "efficient" sense of causal determinism only, although Bohm is not restricted to this. Especially in the *Dialectics of Nature*, Engels introduces the idea of levels, or what he calls "forms of motion". Wood examines the various references and reconstructs a list beginning with mechanical motion and going from the branches of physics, chemistry and biology through to the levels of life and consciousness, the latter including a tentative materialist theory of mind. Engels is especially opposed to attempts at mechanical reductionism, which "blots out the specific character" and "qualitative difference" of non-mechanistic forms of motion.[13] Wood regards this aspect of Marx and Engels's

[9] See Wood (2004), pp. 107–8 and footnote 8, and Meikle (1985), p. 171.

[10] A similar distinction to Aristotle's was made by the great biologist Ernst Mayr, who used the term "ultimate cause" in relation to Darwinian natural selection and that of "proximate cause" for immediate, physiological and mechanical causes. For a recent critical discussion of Mayr's approach with references see Laland et al. (2013).

[11] See Wood (2004), Chaps. 13 and 14 on the complex issue of dialectics in Hegel and Marx and the differences between them.

[12] This is Bohm's terminology. Wood uses the term "mechanistic reductionism" and Meikle uses the term "atomism".

[13] Marx and Engels (1988), pp. 527–532.

philosophy as a "characteristic wrinkle",[14] based on Hegel and Schelling, and does not seem to take it as a significant trait of their work. Meikle, however, goes in for a strong denunciation of mechanical reductionism, or what he terms "atomism", though he bases himself largely on Aristotle.[15] The issue played a crucial role in the debate over "reductionism" between Deborinites and Mechanists in the 1920s, as we will see in Chap. 12 on philosophy and science in the USSR. Despite having no direct knowledge of the 1920s dispute, Bohm clearly saw "mechanism" as a major problem and apparently has some familiarity with the *Dialectics of Nature* arguments.

Besides mechanism, the other major philosophical issues which Bohm raises are "positivism" and the related question of "idealism." He took up ideas from Lenin's work *Materialism and Empiriocriticism*,[16] or most probably a Soviet publication based on Lenin.[17] Lenin's earlier philosophical work is often contrasted unfavourably to his later study of Hegel in the *Philosophical Notebooks*, and has had many criticisms from its first appearance,[18] but the important points for our purposes are: (1) it was directed against the positivist philosophy which was beginning to gain influence at the beginning of the 20th century, due especially to Ernst Mach, and which, to Lenin's horror, was supported in his own Bolshevik Party[19]; (2) it advocated that, philosophically speaking, all the new discoveries in science at the time – electromagnetic radiation, electrons, radioactivity, etc. – were all different forms of matter and the "levels" of matter were infinite. For the dialectical materialist, "matter" should not be limited to the corpuscular matter of 19th century science.

Relating to (1), by "positivism"[20] we mean the philosophical approach that merely correlates sensory perceptions, or experimental results, opposing the claim that such correlations reflect actual relationships among real things, which exist independently of observation.[21] Lenin thought that Mach's positivism led to "idealism", in the subjective sense, i.e. not in the "absolute" sense of Hegel or Schelling. Lenin's idealist is a "methodological solipsist", like the 18th century philosopher Bishop Berkeley, who thinks we can begin only with our experience and that we can never attain knowledge from a world beyond experience.[22] We assume Bohm is using the

[14] Wood (2004), pp. 169–170.

[15] Meikle (1985), especially Chap. 7.

[16] Lenin (1962).

[17] Wilkins (1986), Vol VI.

[18] See Bakhurst (1991), Chap. 4, for a more sympathetic treatment.

[19] For a good introduction to Mach and positivism see Holton (1993), Chap. 1. It is well known that Mach influenced Einstein in his earlier period, see Holton (1993), Chap. 2.

[20] In the sense of Lenin and Bohm. It is now often called anti-realism. David Joravsky uses the term differently to mean limiting "knowledge to the methods and results of the empirical sciences". Joravsky (2009), p. xi.

[21] See the definition Bohm gives in his 1952 paper Bohm (1952b) and the definition in Bohm (1957), Chap. III, Sect. 8.

[22] See Bakhurst (1991), Chap. 4, for more detail. Bakhurst draws the "modest conclusion that there are reasonable, though perhaps not conclusive, grounds to associate Empiriocriticism [i.e. positivism in Bohm's sense] with the doctrines of Lenin's idealist" (ibid. p. 102).

term "idealist" in the same sense as Lenin, and that he sees it as the opposite of "materialism". On point (2), we note that the idea of "levels" does not explicitly appear in Lenin. Although Lenin always bases himself on Engels, giving extensive quotes, *Dialectics of Nature* was not available at that time. Lenin writes only that "[t]he electron is as inexhaustible as the atom, nature is infinite, but it infinitely exists."[23] As we shall see, Bohm expands this idea into the "qualitative infinity of levels."

To understand how Bohm developed his distinctive philosophical approach, one must start from the issues arising from standard "Copenhagen" quantum mechanics and his attempt to expound it in the book "Quantum Theory".[24] Let us review some key features of standard or "Copenhagen" quantum mechanics, developed by Niels Bohr, Werner Heisenberg, Wolfgang Pauli and others in the second half of the 1920s.[25] "Copenhagen" quantum mechanics assumes that quantum systems do not have definite properties until measurements are carried out, and that the theory can only predict the probabilities of the results obtained by these measurements. Previous physical theories using probability had assumed an underlying reality whose details, such as the positions and velocities of very large numbers of atoms in the theory of "ideal" gases developed by Maxwell and Boltzmann, were knowable in principle, if not in practice. However, in standard quantum mechanics, there is assumed to be no such underlying reality at the quantum level until measurements have been carried out.

Certain pairs of properties of quantum systems are called "complementary", such as a particle (which is associated with position) and a wave (which is associated with corresponding momentum or velocity). Unlike the properties of "classical", 19th century physics, according to Heisenberg's uncertainty relation, the more accurately position is measured, the less accurately the momentum can be measured and vice versa, and similarly with other complementary physical variables.[26]

The probabilities in quantum mechanics are given by the Schrodinger wave function that uniquely describes the state of the system.[27] Since there is no other information about the system, the theory is *essentially* random, or to paraphrase Einstein, "God *does* play dice." After measurement, the wave function somehow "collapses" to correspond to the value measured. There is ambiguity in forming the division (or "cut") between the non-classical quantum system and the classical measuring apparatus. Since the observer can be regarded as part of the measuring apparatus, it

[23] Lenin (1962), p. 262.

[24] Bohm (1989).

[25] For a more detailed historical but non-mathematical treatment see Bohm (1957), Chap. III. For a good, more mathematical treatment see Baggott (1992). It should be said, however, that the outline given here must be qualified by the recognition that there was a lack of clarity and agreement among the founding fathers (Beller 1999).

[26] Other examples of such properties are energy and duration, as well as the "spin" of a quantum particle along different axes.

[27] Usually denoted by the Greek letter "psi", ψ, which is assumed to be a solution of Schrodinger's wave equation.

is possible for the measurement process to be interpreted as involving a conscious observer (and hence to support an idealist philosophy).

In practice, the emphasis in the standard approach was, and still is, on mathematical calculations and applications to experiments, in which outstanding successes could be reported, from the late 1920s onward.

In *Quantum Theory* Bohm attempted to develop a rational approach to this strange quantum world. Using the Schrodinger wave function, or usually a kind of concentrated piece of it, a "wave packet", he takes the student through a range of experiments and develops enough mathematics to analyse what is happening. As he writes in a letter to Miriam, "a qualitative "plausibility" argument is more valuable at an early stage in the text than a precise argument full of a forest of symbols."[28] He was basing himself on notes from Oppenheimer's lectures and was influenced by the approach, as he understood it at that time, of Niels Bohr.[29] The book was widely acclaimed for its conceptual treatment rather than the usual formal, mathematical exposition, and even the greatest critic of quantum mechanics, Einstein, thought that "It is the best that could be done with the usual interpretation."[30]

Bohm thus wanted to reveal what was happening in the "collapse of the wave function". He opposed positivistically inclined physicists who "say that after all, only the results of measurements need to be treated, and what happens to the apparatus when nobody looks at it is a "meaningless" question."[31] Opposing this "basically idealist" position, Bohm developed the theory of the measurement process.[32] It is obvious, then, that combating positivism and idealism were central to Bohm's approach.

One would have thought that this was a great achievement and that Bohm could now settle down to a career in teaching and researching theoretical physics. It did not work out to his satisfaction, however. Bohm had argued that there did indeed exist a quantum mechanical reality, whether measurements were being carried out on it or not. He suggested that causal determinism (or "complete" determinism as he called it) should be replaced by "statistical laws". To understand the "complementary" properties of this reality, he had used the idea of "potentialities"[33] But these did not allow him to confidently claim that here was a genuinely "dialectical" feature,

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[28](21, **65**, pp. 225–229). $\Delta x \Delta k \geq 1$ is mathematical shorthand for the Heisenberg relation. Further discussion on *Quantum Theory* is undertaken at (21, **66**, pp. 234–236) and (22, **67**, pp. 238–240). We will leave Bohm's very critical views on mathematics and the role of mathematicians in holding back theoretical physics to the next chapter.

[29]Later he considered it was Heisenberg's approach rather than Bohr's. Bohm and Hiley (1993), p. 18.

[30](21, **65**, p. 226).

[31](22, **67**, p. 239).

[32]Bohm (1989), Chap. 6, Sect. 2 and Chap. 22. In this latter chapter, he analyses the apparatus as well as the quantum system under investigation and concludes that "this problem can be solved without carrying the analysis as far as the stage in which the apparatus interacts with a human observer" (Bohm 1989, p. 606).

[33]See Bohm (1989), Chap. 8 and the reference in his letter to Hanna in early 1950 (14, **1**, pp. 99–100).

something that a Marxist could point to, as a verification of his or her philosophy in nature. As he explained it to Miriam, Bohr's approach had seemed incredibly vague, but it had offered something more, "(i)t seemed progressive because it broke the old mechanist materialist determinism, which left no room for growth and development of something new."[34]. But after all his years of toil, Bohm was unable to reveal genuine dialectics: "dialectically opposing concepts are made just vague enough so that the contradictions between them are avoided."[35] Instead of the synthesis of opposites that a Marxist view requires, "contradictions leading to something new at another level" were thereby lost.

With this disappointing outcome to the completion of his book in the summer of 1950,[36] Bohm spends the next year, or at least part of it, working on the causal interpretation, or the hidden variable interpretation, as he called it then.[37] He submits his papers based on this work to the Physical Review in July 1951.[38] Bohm had clearly decided by then that he could take the complementarity approach no further, and that only a causal determinist approach could place quantum mechanics on materialist foundations. What influenced him to make this turn? Olival Freire notes that Bohm later refers to at least two influences in his sudden shift to the causal interpretation: discussions with Einstein and the "reading of a paper by a Soviet physicist criticizing the complementarity view for its idealistic and subjectivist inclinations."[39]

The influence of Einstein is very clear. For example, in a letter in 1953, Bohm wrote: "In fact, you may remember that after writing a whole book on the usual interpretation of the quantum theory, I abandoned it when presented with arguments which convinced me."[40] As Freire points out, there is no evidence in the letters of a paper written by a Soviet physicist. We review the situation in Soviet physics and philosophy as well as Bohm's responses to it below in Chap. 12. However, since the attack on the idealist interpretation in standard quantum mechanics came from the highest levels in the USSR, which Loren Graham describes as "the most intense ideological campaign in the history of Soviet scholarship,",[41] to the extent that even the term "complementarity" was banned from 1948 to 1960,[42] it would be naive to believe that, given his politics, Bohm was not influenced by this in some way,

[34](21, **66**, p. 235).

[35](21, **66**, p. 235).

[36]See the letter to Hanna (14, **10**, p. 110). Note that Bohm is hoping to work with Niels Bohr on a philosophy book!

[37]In (14, **11**, p. 112), he is "getting interested in the problem of the electron again", which may well relate to this.

[38]Bohm 1952a, b.

[39]Freire (2015), p. 27.

[40]Letter to Einstein, Feb 27, 1953 in Folder C12 in the Birkbeck archives.

[41]Graham (1971), p. 74.

[42]ibid, p. 80.

probably through Communist Party publications, whether he read material from a Soviet physicist or not.[43]

What Bohm views as the essential characteristics of his causal interpretation is explained in a letter to Melba, responding to Phil Morrison, a leading physicist and Communist Party member, who thought Bohm's philosophy was correct, but the standard theory was "simpler".[44] The probabilistic aspect of his theory, Bohm explains, is "a result of chaotic collisions with atoms, molecules, etc., undergoing random thermal motion", and so the "probabilities have the same origin as those of classical statistical mechanics", i.e. the result of an extremely large number of causally determined processes and not some unexplained, essentially random, process.[45] In Bohm's theory, quantum systems have both a wave function and a particle or particles. Therefore two atoms, for example, can have the same wave function but may not be identical, and there exist also particles which, though unobserved, can be at different positions. To emphasize his point, Bohm notes that in the apparently "simpler" standard theory, a uranium atom exploding tomorrow and another one exploding in two billion years have exactly the same wave function and so are indistinguishable. In contrast, in his causal interpretation, "the two uranium atoms are not "physically identical" because each of them has a particle in it in a position that will determine when it will disintegrate." So whilst admitting that this is not "simpler", in that it makes for an additional hypothesis, "namely that there exists an as yet unobserved particle", Bohm can clarify "things that were previously arbitrary".[46]

Bohm's new causal interpretation certainly seemed to deal with the positivism and idealism of the standard theory. But hadn't he also re-opened the door to that very "old mechanist materialist determinism" which he had once thought Niels Bohr had

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[43] See (26, **94**, p. 311): here Bohm states that a "vigorous criticism of the foundations of quantum mechanics is going on in the "East"". Loren Graham refers to a 1951 paper by the Russian physicist D.I. Blokhintsev, which was critical of the standard interpretation. It advocated his own, distinctive statistical ensemble approach, which is not at all similar to Bohm's. However, according to Graham, Blokhintsev dismisses the usual objections to "hidden variable" theories and acknowledges that such a "theory of quantum mechanics might at some future date permit a numerical description of the individual microparticle, although at the present time he considered such a description to be impossible." Graham (1966). It may be that an earlier version of Blokhintsev's work had reached the US and an English translation was obtained by Bohm.

[44] (17, **37**, pp. 151–153).

[45] He clarifies this in a paper following up the original 1952 papers (Bohm (1953)), referred to in mathematical notation by $P \rightarrow |\psi|^2$ and discussed in a number of letters (23, **74**, p. 257), (23, **78**, pp. 264–265), (24, **83**, p. 277), (25, **88**, p. 293), (26, **93**, p. 308), (26, **94**, p. 312), (17, **37**, p. 151) and (17, **38**, pp. 154–155). Another version, with input from Vigier, was published in Bohm and Vigier (1954).

[46] Note that in explaining his theory to Morrison, Bohm only uses the wave function and not the "quantum potential" concept derived from it, which features in the 1952 papers. He only discusses the "quantum potential" aspect of his theory in the letters once, in (25, **90**, p. 298), explaining how hypotheses are put forward. In Bohm (1957), Chap. 4, Sect. 4 he considers a general "quantum force" rather than a quantum potential, the nature of which, it is presumably hoped, will be clarified in the relativistic generalizations of the theory. See also Hiley and Peat (1987), p. 37, where Bohm explains that the instantaneous "entanglement" of distant particles was seen to contradict relativity and was regarded as a "serious difficulty to be resolved with the aid of further new orders.".

successfully dealt with, in other words, was this not a reiteration of the problem of a mechanist ontology referred to above? Had his introduction of causal laws brought in the "nightmare of a mechanically determined universe that follows an inevitable course"[47]? It is to counter this threat that Bohm developed his own distinctive philosophy of an infinite number of levels.[48] With such qualitatively distinct levels "we can have complete causality at every level, in the sense that we can use this causality to change the world in a predictable way, with the error in the predictions dependent only on our level of knowledge;" but with the addition that "we can in no sense conceive of the world as completely determined".[49] In the early 1952 period we find a number of letters to Miriam setting out Bohm's infinite levels philosophy in relation to physics[50]; note also the letter to Hanna on this issue.[51] The reader may also find Hans Freistadt's 1956 paper of use here.[52] Freistadt was a Marxist physicist who lost his job in the McCarthy witch-hunt. He was supportive of Bohm's views, and was apparently in contact with Bohm via Melba Phillips.[53] Note that Freistadt has a reference to the 1951 paper, in Russian, by the Soviet physicist Blokhintsev, already referred to above.

In these letters, Bohm wants to explain the concept of matter and some aspects of dialectics, from his infinity of levels standpoint. He proposes that "in some aspects at least, matter is indestructible and uncreatable" and "matter as a whole in its infinity of properties and potentialities is eternal". This would seem to make change and transiency impossible. But with the levels approach:

> The things at each level, are made up of smaller elements at a more fundamental level, and it is the motion of these more fundamental elements (not usually directly visible to us, except with the aid of elaborate scientific research) which causes the appearance and disappearance of the things existing at a higher level.[54]

By considering his work on plasma physics, Bohm points to examples where the behaviour of an "individual" at one level is "collectively conditioned" by a higher level. Thus:

> The universe cannot be analyzed into a series of components, each of which are the constituents of the next higher level, and each of which determine the higher levels in a purely analytic way. For the higher levels will also always help determine the character of things that may exist at the lower levels. Thus, every level is in a sense, just as real as every other, since the "whole picture" cannot be deduced by starting at the "lowest level" and working upward.[55]

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[47] (22, **73**, p. 254).

[48] In a November 1951 letter to Miriam, (20, **58**, p. 205), it is clear that Bohm expects Miriam to know about his infinity of levels approach, so presumably he first developed the idea at Princeton.

[49] (22, **73**, p. 255).

[50] (21, **65**, pp. 227–229), (22, **68**, pp. 245–246) and (22, **73**, pp. 254–255).

[51] (15, **20**, pp. 123–124).

[52] Freistadt (1956).

[53] See the distribution list in (19, **52**, p. 180).

[54] (21, **65**, p. 227).

[55] (22, **68**, p. 246).

New things can come into existence:

> For if we have a finite number of causal levels, then the future is already contained logically in the present, but not if we have an infinite number. The appearance of qualitatively new things with time is possible with an infinite number, because the effects of the limitless number of lower levels can always surge up into a higher level (and vice versa) producing qualitative [missing words] describable as a rearrangement of things already in existence.[56]

It should be noted that in this earlier period Bohm uses the concept of causality entirely in a narrow sense, which, in philosophical terms, may be called "efficient causality".[57] He also seems to be using an ontology of "things" or "elements" in a mechanistic sense, in line with the physics of particles, employing the infinite levels approach in order to get beyond this restriction. In the chapter below on probability and chance, we will see a similar restriction at this earlier stage, treating causality as fundamental and chance, or "chaos", as derived from it. There is a distinctive change in Bohm's philosophical approach after 1953, although this is only clearly brought out in two letters to Melba[58] and in the later letters on probability and chance. Almost certainly, this change is due to the visit of philosopher-physicist Mario Bunge, who came over from Argentina to São Paulo as Bohm's postdoctoral student from April to October in 1953.[59] It is possible that some of the change in Bohm's views, especially on probability and chance, is also due to Professor Mario Schönberg, as detailed in Chap. 9.

Bunge's views in that period were presumably in a state of flux, between the Marxism of his 1951 paper[60] and the "analytical", though still materialist approach of his later *Causality and Modern Science* book.[61] The outcome of the Bohm-Bunge interaction was a definite clarification of Bohm's views on mechanism as well as on causality and determinism. It should be noted that Chap. I of *Causality and Chance* has similar material to Bunge's *Causality and Modern Science*. The ideas of one-to-many and many-to-one causality, for example, appear in both,[62] but do not appear at

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[56] (22, **73**, p. 255).

[57] The "causal laws" in (22, **73**, pp. 254–255).

[58] (18, **43**, pp. 163–165) and (18, **46**, pp. 170–173).

[59] Dates given by Mario Bunge in an email to the author, 21.09.2015. There is little to indicate Bunge's visit in the letters: Bohm refers to Bunge and his wife as "nice people" in (28, **110**, pp. 360–361) and refers to Bunge's view of George Yevick, (29, **111**, p. 370). Bohm also visited Bunge in Argentina on his way to Israel, early in 1955 (18, **49**, p. 175).

[60] Bunge (1951).

[61] Bunge (2009). In his email to me, Bunge says he had "just been weaned from Marxist philosophy." Bunge also writes that he "asked him [Bohm] why he was wasting his time reading that garbage" (i.e. Hegel). Bohm replied "Because it inspires me." Bunge ruefully adds "Fortunately his physics did not suffer". It is difficult to reconcile this story, based on hindsight, with the many references to Hegel in Bunge (2009). There are more fulminations against Hegel in Bunge's autobiography (Bunge 2016), as well as attacks on Bohm's later "New Age" views, and the comment about his own philosophical development: "I wasted too much time trying to decipher Hegels riddles, and it took me several years to realize that he had started the Counter-Enlightenment and had invented the trick of passing off absurdity as depth" (ibid p. 102).

[62] Bohm (1957), Chap. 1, Sect. 7, Bunge (2009), Sect. 5.1.

all in the letters. Bunge's *Causality* book, though clearly moving away from his earlier Marxism, should be recommended for its materialist critique of the still dominant philosophical view on causality, which dates back to the 18th century empiricist philosopher Hume, proposing that causality is merely the "constant conjunction" of observations, and denying the existence of such a thing as objective necessity.[63]

Bohm sets out his view of mechanism in the second of the two letters to Melba[64]:

> (1) Everything is made of certain basic elements which themselves never change in essence (i.e. qualitatively). (2) All that these elements can do is to undergo some quantitative change according to some fixed laws of change. For example, if they are bodies, they can move in space. If they are fields, they can change their numerical values, etc., etc. But the basic elements themselves never undergo qualitative change.

Mechanism is thus criticized from the standpoint of an *ontology*, relating to the fundamental nature of reality, in line with Marx and Engels' view of it. In earlier letters,[65] Bohm refers to "deterministic mechanism", especially when he discusses quantum mechanics and the "infinity of levels", and this means that he understood the "basic elements" to be governed by causal determinism. He now wants to "sharpen the distinction between causality and mechanism". The earlier approach would seem to relate only to corpuscular matter, but here the ontology is broadened to include electromagnetic radiation or "fields".[66] In the first of the two letters to Melba,[67] Bohm has already extended the definition of mechanism to include the "mechanistic indeterminists" of standard quantum theory "who insist that in the quantum of action, we have reached an ultimate, indivisible, and unanalyzable entity, which will never be found to have a structure understandable in terms of a deeper level."[68]

Note that Bohm makes the important point that mechanical laws are not to be simply rejected, but that "[i]n certain limited domains (the limits of which of course, cannot be known a priori) mechanical laws will surely be good enough approximations."[69]

The two letters to Melba are thus an all too brief outline of a position much more fully elaborated in the first three chapters of *Causality and Chance*. We may presume that in 1954, with work on the causal interpretation vigorously continuing, as set out in Chap. 8 below, Bohm was hoping that his approach would come to be seen as going beyond the mechanism which had so far characterized physics, and as leading to a possible way out of what some saw, with a nod at Lenin, as the "Current Crisis

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[63] For a readable summary of the range of modern philosophical views, mainly Humean, see Mumford and Anjum (2013).

[64] (18, **46**, p. 170).

[65] e.g. (21, **66**, pp. 235–236).

[66] See more detail in Bohm (1957), Chap. 2. This differs from the view of some advocates of "organism" and "holism", who would include fields under that particular heading, e.g. Dusek (1999).

[67] (18, **43**, p. 164).

[68] As explained further in Bohm (1957), 3.

[69] (18, **46**, p. 171). Similarly in Bohm (1957), Chap. 5, Sect. 4, he writes that his infinite levels philosophy enables us "to retain all the positive achievements that were made possible by the development of mechanism."

in Microscopic Physics".[70] That did not happen, and Bohm admits in 1957 that his approach had also often been criticised as too mechanical. But it still, he argues, "may be a good starting-point from which qualitatively new developments are likely to arise."[71]

Bohm also gives a brief indication of how to go beyond mechanism in a philosophical sense, and this is the subject of his last chapter in *Causality and Chance*. It is partly, of course, by means of the "qualitative infinity of levels". But he also wants to extend the type of change that matter can undergo, moving beyond the more limited "efficient" causality of mechanism:

> But more general types of change are possible. Thus, we may have qualitative change, as in evolution or in embryology. The appropriate causal laws then govern the qualitative changes, and tell which things will change into what and under which conditions.[72]

This broader usage is developed in *Causality and Chance* and is an essential part of Bohm's attempt to move beyond mechanism in physics. Of course, it is always permissible to extend a definition. But in order to avoid confusion, it is important to note that "causality", used in this broader sense by Bohm, refers not to "efficient" cause but to the "teleogical" change in the "organicist" ontology of classical Marxism, as referred to above.[73]

There is clearly a problem facing Bohm that refers to the key area of natural science, biology, to which, as we pointed out at the beginning of this chapter, such an organicist ontology is highly relevant. Although criticizing Lysenko's methods, as late as March 1955 Bohm thinks he was basically correct against geneticists.[74] Bohm's reference to evolution and embryology in these letters to Melba is, therefore, only a passing one. Perhaps because of his isolation in Brazil, he was unable to grasp Lysenkoism's fraudulent character, or to make any reassessment of Darwinian evolution from a Marxist standpoint at this stage, although, by the early 1950s, many Communist Party members and supporters were becoming aware of the complete disaster in Soviet genetics.[75] By the time he writes *Causality and Chance*, Bohm appears to have given Darwinian evolution more thought.[76]

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[70] The title of Bohm (1957), Chap. 4, Sect. 7. Lenin (1962), Chap. 5, Sect. 1, is entitled the "Crisis in Modern Physics", following the lead of Henri Poincaré.

[71] Bohm (1957), Chap. 4, Sect. 9.

[72] (18, **46**, p. 171).

[73] In *Causality and Chance*, Bohm refers to causal laws related to the "mode of being" of things, in Chaps. 1 and 6, and the "Process of Becoming" in Chaps. 5 and 8.

[74] In (19, **50**, pp. 178–179) he writes of "the extremes to which Lysenko went in criticizing backward trends in biology". Previously, in March 1953 (26, **97**, p. 320), he wrote of "Lysenko's excessively dogmatic presentation of his basically correct point of view".

[75] See Brown (2012) for details of and on the response of the famous Communist physicist J.D. Bernal. Although Bernal wrote an appalling eulogy to Stalin after his death in 1953, he did recognize the importance of the discovery of DNA in the same year.

[76] See the references to the theory of evolution and "natural selection" in Chaps. 1 and 6, and the "well-known evolution of the species" in Chaps. 5 and 8, where Bohm also considers evolutionary processes in geology, astronomy and cosmology.

This chapter has concentrated on the relatively small number of letters relating to the philosophy of physics and to the development of the ideas in *Causality and Chance*. An examination of Bohm's numerous letters concerning probability and the relation between causal and statistical laws is left to Chap. 9. However, we should also note that the philosophical concepts that Bohm uses in his physics, and that can be explained fairly precisely as we attempted above, are employed by Bohm in a much looser sense and quite extensively throughout these letters, when referring to social and political issues, issues relating to science and society, and so on.

A few examples will illustrate Bohm's type of socio-political analysis. Firstly, an example on positivism, where Bohm is concerned, not with the application of philosophy to quantum mechanics, but with what he sees as a problem with physicists:

> The flexibility of positivism is amazing, for among [experimental] physicists in [the] U.S., there is a belief that physics flows solely from empirically observed data, or "operations", which is also combined with a belief that theorists take these numbers, and with the aid of a few geniuses like Dirac, produce equations that fit these numbers.[77]

For Bohm, positivism is not just confined to scientists, but is a philosophical problem of society in general, with a related view of "relativism":

> Thus, a characteristic attitude of people toward life is a cynical one, "relativistic", in the sense that morals and responsibilities are said to be determined only by the prevailing society. If one happens to be in a Nazi society, then one naturally adopts Nazi morals, etc. In America, one adopts the prevailing "American Way of Life".[78] This is the counter-part of positivism, for it says that there is no objective material basis for morals, but that all is determined by a commonly agreed upon convention, which introduces "order" into the system of behaviour.[79]

Secondly, Bohm sees mechanism or mechanical materialism as dominating current social thought:

> It was in dealing with nature that man was forced to produce his first objective and clearly thought out concepts, and in this way developed a form of thinking that we hope can now be applied to human beings and to society. But the experience gained in this pursuit up to now has largely been seen in terms of the distorted idea that "things are what they are, and nothing more". Mechanical materialism is a form of this idea.[80]

Such scattered and quite numerous philosophical remarks relating to society are usually made in a pejorative sense. The "infinity of levels" idea, however, is used by Bohm in a more optimistic sense:

> But in this regard, human nature is no different from Nature in general; for according to the ∞ of levels, all properties can be altered with sufficient changes in conditions. Thus, the ∞ of levels is an integral part of a better view of Nature in general, and of human nature in particular.[81]

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[77] (17, **35**, p. 148).

[78] Bohm has a profound hatred of the "American Way of Life", to which he repeatedly refers.

[79] (20, **59**, pp. 206–207).

[80] (21, **66**, p. 233) See also (32, **123**, pp. 430–431).

[81] (27, **101**, pp. 332–333).

One could argue that these social or political aspects of Bohm's philosophical thought, as shown in these few examples – there are many more – are not separate from his thoughts on physics, and also can be seen to provide a motivation for his scientific work. I have taken the view that there are, in fact, differences between social criticism and philosophy of physics, and that Bohm's profound knowledge of physics does give more validity to his scientific philosophy. It can also be placed firmly in the Marxist tradition that was largely suppressed by Stalin. I have, therefore, only briefly considered his far less well-defined social philosophy in Chap. 11, in the context of looking at his politics as a whole.

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