Physicalism and Ontological Holism

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Abstract

The claim of this paper is that we should envisage physicalism as an ontological holism. Our current basic physics, quantum theory, suggests that, ontologically speaking, we have to assume one global quantum state of the world; many of the properties that are often taken to be intrinsic properties of physical systems are in fact relations, which are determined by that global quantum state. The paper elaborates on this conception of physicalism as an ontological holism and considers issues such as supervenience, realization of higher-order properties by basic physical properties, and reduction.

Keywords: physicalism, holism, relations, space-time, quantum physics, Humean supervenience.

I. Introduction

Physicalism is the claim that everything that exists is something physical. As Wilfrid Sellars puts it, adapting the famous saying of Protagoras, “in the dimension of describing and explaining the world, science is the measure of all things, of what is that it is, and of what is not that it is not” (1963, § 41, 173). Replace “science” with “physics” in this quotation, and you have the idea that moves physicalism. However, physics, not to mention science as a whole, is far from being a unified theory. Ontologically speaking, we assume that macroscopic systems are composed of microphysical ones. It therefore makes sense to characterize physicalism in such a way that it is microphysics on which we should focus. The claim then is that everything that exists is something microphysical – in the sense that everything is realized as some sort of a microphysical arrangement.

No one maintains that our current microphysics “is the measure of all things, of what is that it is, and of what is not that it is not.” But the idea in physicalism is that our current microphysics is on the right track to discover the truth of the matter. (As regards the problem for physicalism posed by the tension betweeen our current and a future, better physics, see Crane and Mellor 1990 and the reply by Pettit 1993). To gain an idea of what physicalism might look like in concrete terms, it is therefore reasonable to refer to our current microphysics. My claim is that, *contrary to* [320] *what one might expect, contemporary microphysics suggests that we have to conceive physicalism as an ontological holism*. By ontological holism, I mean the position that (1) there is only one thing, that is, that everything that exists is a way of being of the one thing, and that (2) all properties are realized as relational properties or relations within this one thing. (For an elaboration on a conception of holism, see Esfeld 1998).

I shall base that claim on current quantum physics and quantum field theory in particular (which I will examine in sections 4 and 5). However, before going into quantum physics, I shall prepare the terrain by first considering the claim that modern physics as such suggests a holism, because it treats only types of functional dependence (see section 2), and by then presenting a space–time model that gives us an idea of what physicalism as an ontological holism can look like (see section 3). Once I will have developed the argument for quantum physics suggesting an ontological holism, I will briefly consider what physicalistic themes such as supervenience, realization of higher-order properties by basic physical properties, and reduction can look like in that framework (section 6).

II. Does Physics Treat Only Relational Properties?

It may seem that modern physics as such suggests a holism. Some scholars (e.g., Rombach 1966) regard the transition from the Aristotelian and medieval view of nature to the modern view of nature as a transition from an ontology of substances or essences to an ontology of functions. Instead of treating intrinsic, essential properties of substances, the modern view considers types of functional dependence among physical systems in mathematical terms. Consequently, according to this tradition of scholarship, conceiving nature along the lines of modern science means conceiving nature as a network of relations. Starting from the claim that science deals exclusively with quantities, this tradition considers quantities as relational properties.

Let us assume for the sake of argument that the modern view of nature consists in replacing a description of essences with a description of functions. The mathematical description of the value of a physical property of a system – for example, its length, width, depth, or mass – can be seen as a description of the relation of that value to the value of the same properties of other systems. Saying that a system is two centimeters long and weighs six grams can be taken to indicate its relation to other systems – that is, to indicate that it is longer or shorter, heavier or lighter, than other systems. But even if one grants that the description of the values of physical properties consists in indicating relations, it does not follow that the properties of length and mass are themselves relational. This consideration does not preclude that an object that is the only physical thing in a possible world can have a certain geometrical shape (such as being spherical or being square) and a certain mass. Thus, even if physics conceives properties in relational [321] terms, this does not imply that these properties themselves are relational. We cannot build a claim for physicalism as an ontological holism on that basis.

However, if physics conceives properties in relational terms, this may pose a problem for physicalism. Physicalism takes physics to be a guide to ontology. But if physics describes properties only in relational terms, this may leave us ignorant of what these properties are in themselves. Here is what Frank Jackson says on this point in his recently published John Locke lectures:

> When physicists tell us about the properties they take to be fundamental, they tell us what these properties *do*. This is no accident. We know about what things are like essentially through the way they impinge on us and our measuring instruments. It does not follow from this that the fundamental properties of current physics, or of "completed" physics, are causal cum relational ones. It may be that our terms for the fundamental properties pick out the properties they do via the causal relations the properties enter into, but that at least some of the properties so picked out are intrinsic. They have, as we might put it, relational names but intrinsic essences. (1998, 23)

This quotation emphasizes the point I just mentioned: Treating properties in relational terms does not imply that these properties themselves are relational. However, Jackson then goes on to concede the possibility "that we may know next to nothing about the intrinsic nature of the world" (23). Given the treatment of properties in relational terms, this is a possibility that we have to grant. But this possibility should not prevent us from considering what might be the most plausible ontology on the basis of the knowledge that we have.

Jackson repudiates the view “that the nature of everything is relational cum causal, which makes a mystery of what it is that stands *in* the causal relations” (23). However, if we generalize this view in such a way that it concerns not only causal relations, but all relations, there is nothing mysterious about it. As long as “relational” is not limited to the relations between physical things and persons, there surely is a possible world in which physical things have only relational properties. That is to say, in such a world, all the qualitative properties of any physical system apart from the whole world are the relations between this system and other systems. (Qualitative properties are all and only those properties whose instantiation does not depend on the existence of a particular individual.)

Whereas one can maintain that dispositions need a nondispositional explanatory ground (Smith and Stoljar 1998), relational properties do not in general require a nonrelational explanatory ground; relations do not depend on intrinsic properties to support them. This is evident in the case of spatio-temporal relations, and it will become the more clear when I consider the quantum relations of entanglement in section 4 below. If our best science tells us that the basic properties that are instantiated in our world [322] are relational ones, this may be the truth of the matter. The point is that our physics accounts for what it is in physical things that makes them have the known physical effects on us. The upshot of this consideration is this: It may be that our world has an intrinsic nature that is not taken into account in our physics and, moreover, of which we cannot gain knowledge in any future physics. However, it is not necessary to settle for a metaphysics that regards us as being ignorant of the intrinsic nature of things. Even if it turned out that all the properties of which we gain knowledge were relational ones, nothing would hinder us from regarding the resulting description of the world as being in principle a complete one.

III. A Space-Time Model

In the following discussion I shall consider versions of an ontology according to which all physical properties are in the final analysis relational or are tied to relational properties. Such an ontology is a presupposition for an ontological holism. To be more precise, the step on to an ontological holism, as defined at the end of section 1, then consists in conceiving these relational properties as relations within one thing instead of conceiving of a plurality of things that stand in these relations. To give an idea of what physicalism as an ontological holism can look like in concrete terms, I first draw attention to a space-time model and then review the evidence for an ontological holism in quantum physics.

However much atomistic ideas may prevail in classical physics, we can find an ontological holism even in some of those philosophers who are hospitable to modern science. The most prominent example is Spinoza. In the first book of his *Ethics*, Spinoza sets out an ontology according to which there is only one substance; everything is a way of being, a mode, of that substance under one of its attributes; the physical world is the substance under the attribute of extension. According to the interpretation of Bennett (1984, Chapter 4), as far as the physical world is concerned, Spinoza identifies the substance with space. I shall use Bennett’s interpretation to set out a space-time model of an ontological holism. (I shall leave aside the exegetical issue of whether or not Bennett’s interpretation is an adequate representation of Spinoza’s views.)

Bennett himself does not use the term “holism”. He only speaks of monism. He sums up his position in these terms:

> It suggests that there is just one substance—namely, the whole of space—regions of which get various qualities such as impenetrability, mass, and so on, so that any proposition asserting the existence of a body reduces to one saying something about a region of space. (§ 22.1)

Hence, there are no physical systems such as particles or fields in addition to space. A body with all its properties is realized as certain properties of [323] regions of space. However, the physical properties of the regions of space are not identical with the properties that we ascribe to the bodies that we localize in these regions. Bennett marks with an asterisk (*) the concepts that refer to properties that are predicated of regions of space. He writes:

> To say that the puddle is slimy is to say that a certain region of space is slimy*—i.e., has that property of regions which we conceptualize by saying that there are slimy things in them. (§ 23.5)

Why is this position an ontological holism? Physical space, conceived as a three-dimensional, Euclidean space, is the same thing as matter. According to this conception, physical space is a continuum. Whatever account of space as a continuum one accepts, if there are proper parts of space such as regions or points, there cannot be only one thing that has the property of being a region or a point of space. Something can have the property of being a point or a region of space only if there are other points or regions that run through the whole space. What makes something a point or a region of space is relational properties or relations to other points or regions within the whole of space, if space is a continuum. There are no qualitative non-relational properties that could serve as a basis on which these relations or relational properties could supervene. Thus, the property of being a point and the property of being a region of space and all the properties that these properties include are relational. In a possible world in which matter and space are the same thing, all the physical properties that are instantiated in this world are realized as arrangements of some of the properties that being a point or being a region of space includes. Consequently, all the physical properties that are instantiated in such a world are realized as relational properties. This is an ontological issue. It is independent of the issue whether or not we have to describe physical properties in relational terms.

As presented so far, this conception employs the notion of a plurality of points or regions of space that are the ultimate subjects of the predication of properties. In a second step of his interpretation of Spinoza, Bennett (1984) eliminates the ascription of properties to the regions of space. Space itself is the only subject of predication. All propositions are to be formulated in such a way that all properties are directly predicated of space. In order to localize the instantiations of the properties, an adverb such as the indexical word “here” or “there” has to be added. Instead of saying “Region *x* is *F*” we have to say something like “Space is *F* there”. Bennett sums up his two steps in these words:

> To say that the puddle is slimy is to say that a certain region of space is slimy* – i.e., has that property of regions which we conceptualize by saying that there are slimy things in them. And to say that there is a slimy* region is to say *that space is slimy* locally* – where “locally” is just my placeholder for whatever adverb would do the required job. (§ 23.5)

[324] Independent of whether or not this suggestion succeeds in reducing the reference to regions of space to the reference to space, the point as regards ontological holism is this: We begin with properties of the whole, that is, the whole space. These properties manifest an internal structure within the whole. They are not properties such that space is *F* and *G simpliciter*. Instead, space is *F* in one point or region and *G* in another point or region. *We thus have properties that are predicated of space as a whole, but that are such that they introduce something as a point or a region among other points or regions within space*. These properties make something a part of space – in the broad sense of a part that does not imply independent existence and is not itself an ultimate subject of the predication of properties. I submit that (1) parts of the whole in this sense are necessary for ontological holism to gain any plausibility and that (2) such parts do not compromise the claim of ontological holism according to which there is only one thing (so that everything is a way of being of the one thing).

This model can readily be adapted to current physics by replacing the continuum of a three-dimensional Euclidian space with the continuum of a four-dimensional space-time that has the structure of a Riemannian manifold, that is, that is curved. We then have a space-time model of an ontological holism. Furthermore, working with four-dimensional space-time facilitates the account of motion within this model: What we consider in common sense as the motion of a body through space can be conceived as a continuous sequence of space-time points or regions that have similar physical properties. For all practical purposes, owing to the similar physical properties, such a sequence of space-time points or regions can be treated as one individual.

One may wonder whether this model merely describes a conceptual possibility. There was a program for a further development of the physics of Einstein's general relativity that set out to show that there is only space-time and that every physical property is realized as a geometrical property within space-time. This was the geometrodynamics of Wheeler (1962). Geometrodynamics showed how this model can work in concrete terms by conceiving physical properties in such a way that they are realized as geometrical properties. However, geometrodynamics failed for physical reasons (see, in particular, Stachel 1974). Wheeler himself repudiated geometrodynamics as an ontology that acknowledges only space–time (Misner, Thorne and Wheeler 1973, § 44.3–4, in particular 1205). Thus, there is a possible world in which physicalism holds as an ontological holism in the described sense of there being only space–time. However, the current state of the art in physics suggests that our world is not such a world. Nonetheless, we can use the space–time model as a guideline to comprehend how physicalism might look as an ontological holism in a world based on quantum physics.

[325] IV. Holism in Quantum Mechanics

Quantum theory is our most basic physical theory. Therefore, if we wish to know what concrete shape for physicalism is suggested by current physics, we have to consider quantum theory. When I speak of quantum theory or quantum physics without further qualification, I mean both quantum mechanics and quantum field theory. However, in this section, I shall be concerned only with quantum mechanics. I shall take up quantum field theory in the next section. Quantum mechanics treats atoms and subatomic systems such as neutrons, protons and electrons.

The most striking feature of quantum mechanics is what is known as the *entanglement* of the states of two or more quantum systems (Schrödinger 1935, 555). Consider the simplest example (Bohm 1951, 611–22): Spin is a physical property that is treated only in quantum theory. There are systems of spin-1/2 particles such as electrons and neutrons. In such systems, the spin in any of the three orthogonal spatial directions can take only two definite numerical values. Call these values “spin up” and “spin down.” Imagine that two spin 1/2-systems are emitted together from a source. After the emission, the interaction of the systems ends, because they fly apart in opposite directions. Nonetheless, however far apart in space these two systems are removed, the spin state of the whole, that is, the joint spin state of these two systems, taken together, is a superposition of the first system’s spin up and the second system’s spin down with the first system’s spin down and the second system’s spin up in any direction. This state is known as the *singlet state*.

The crucial point is that neither of the two systems is in a state of either spin up or spin down in any direction. Consequently, neither system has a definite numerical value of any local spin observable. (The properties of a quantum system are commonly referred to as observables. Observables are not tied to measurement, although the term suggests the contrary). A *local observable* is an observable that relates only to one of the two systems. Spin in *z*-direction of the one system and spin in *z*-direction of the other system are examples of local observables. Only the whole, which consists of these two systems, has a definite numerical value of a global spin observable, namely, the total spin; this observable has the value zero. A *global observable* is an observable that relates to the whole.

In the Schrödinger representation, the state of a system at a given point in time determines the probability distributions of the values of those properties of the system at this point in time whose value can change during the existence of the system (such as position, momentum, or spin in any direction). These properties can therefore be considered as *state-dependent properties*. By contrast, properties such as mass and charge are state-independent; their value does not change during the existence of the system.

Consider again the singlet state: Assume that we measure the spin of one of two such systems in one direction, chosen arbitrarily. Given the [326] direction measured and the outcome of this measurement, the probability for the outcome of a spin measurement on the other system is changed (unless the spin is measured on both systems in orthogonal directions). As regards a spin measurement on the other system in the same direction, it is even possible to predict the outcome with certainty, that is, either “spin up” or “spin down” has probability one. These correlations between outcomes are well confirmed by experiments – even by experiments that carry out measurements on two such systems at a space-like distance in the sense of special relativity. (The first such experiment was performed by Aspect, Dalibard and Roger 1982). The famous theorem of Bell (1964) says, to put it in a nutshell, that the emission of the two systems from the source cannot be a common cause that accounts for these correlations.

If there is entanglement, the states of two or more systems are thus entangled in such a way that only the whole, that is, these systems taken together, is in what is known as a *pure state*. In the example of the singlet state, only the whole has a definite numerical value of a spin observable, namely the total spin; but neither of the two systems is in a state in which it has a definite numerical value of a spin observable in any direction. Hence, entanglement means that two or more systems are related in such a way that only these systems taken together have properties of certain kinds with a definite numerical value, for example, a property of the kind spin with a definite numerical value. This way in which two or more systems are related gives rise to the observed correlations between the outcomes of a measurement of certain local observables of each of these systems, for example, correlations between the outcomes of a measurement of local spin observables in each of these systems.

Although only the state of these systems taken together is a pure state, it is possible to give a description of each of these systems that can be regarded as a sort of state description. One has to work with the notion of a mixed state, or what d'Espagnat calls an improper mixture (1971, Chapter 6.3). This is the term for a description that in the case of entanglement of the states of two or more systems contains all the information that is available about each of these systems considered independently of the other system(s). In the example of the singlet state, the description of the system in terms of a mixed state contains the probability distributions for a measurement of all the local spin observables of each of the two systems. But this description ignores the correlations between the possible values of these observables that can be acquired in measurement. Thus, this description ignores the disposition of each system to acquire a certain value of spin in a given direction relative to whatever value of spin in a given direction the other system acquires. The description in terms of a mixed state is identical for the two systems. Consequently*, in the case of entanglement, the description that relates to each of the systems in question does not completely specify the local observables of this system*. Furthermore, this description does not specify the state of the whole, that [327] is, the state of these systems taken together. It is possible that the same description in terms of a mixed state applies to two systems that are not in the singlet state.

This point holds independently of the way in which one interprets the correlated probability distributions of local observables of two or more systems in the case of entanglement. For instance, admitting properties with indefinite values or admitting potential properties of each of the two systems does not change the fact that these properties are identical for the two systems, and that they fail to determine the global observables of the whole. Hence, *in the case of entanglement, it is only the pure state of the whole, such as the singlet state, that completely determines the local properties of the parts and their relations* (to the extent that these properties and relations are determined at all in quantum physics). Therefore, quantum entanglement is considered as a sort of holism. (For proposals to spell this holism out in philosophical terms, see Teller 1986, Howard 1989, Healey 1991).

Consequently, the dispositions of each quantum system that is part of such a whole do not have to be conceived as bare dispositions; their explanatory ground is properties of the whole (such as, in the singlet state, the global observable of total spin). There is no reason to consider these properties of the whole as dispositions, because, in the formalism of quantum theory, they each have a definite numerical value. Furthermore, although interactions can give rise to entanglement, the relations of entanglement between quantum systems are distinct from causal relations. The two systems in the singlet state in an experiment such as Aspect, Dalibard and Roger's are removed in space in such a way that there is no longer any considerable interaction between them. Nonetheless, their spin states are entangled. A causal relation between two or more systems presupposes that the related systems each have well-defined local properties. If this were not the case, a causal dependence between a change in local properties of one of the systems in question and the other system could not be formulated. As far as entanglement is concerned, by contrast, there are no well-defined local properties of each of the systems. Thus, none of the arguments that are raised against dispositions or causal relations as the fundamental building material of the world applies to the quantum relations of entanglement.

Cases such as the singlet state are not at all exceptional. A conceptually similar example can be built by considering two systems whose states are entangled with respect to position and momentum (Einstein, Podolsky, and Rosen 1935). The two systems taken together have a definite numerical value of the global observables relative distance and total momentum. But neither of the two systems has a definite numerical value of position or momentum. What is more, whenever we consider a quantum whole that has two or more quantum systems as proper parts, quantum theory tells us that, apart from very exceptional cases, the states of these systems are entangled. This consideration applies also to the whole of nature at the [328] level of quantum systems. Consequently, in the end only all quantum systems taken together are in a pure state (see, for instance, Scheibe 1991, 228). This is an ontological consequence of quantum mechanics. It does not imply that anyone is or should be in the epistemic position to write down the pure quantum state of the world.

Thus, as far as the state-dependent properties of microphysical systems (such as position, momentum, and spin) are concerned, quantum mechanics suggests the following ontology: (1) These properties are relational in the sense that each system does not have these properties separately (Howard (1989)); all there is to these properties are the relations among these systems, which make up the entanglement of their states, in whatever way one might interpret the entanglement, and (2) These relations are completely specified only by the pure state of a whole, which is in the last analysis the whole of all quantum systems.

The argument so far shows only that the state-dependent properties of microphysical systems are relational, but not that all their qualitative properties are relational. Nonetheless, state-dependent properties are essential to a microphysical system: Nothing is a microphysical system that does not have a position, a momentum, and a spin in some sense – that is, in the sense of being related with other systems in such a way that only the whole has properties of the kind position, momentum or spin with a definite numerical value (that then give rise to correlated probability distributions of local observables of the related systems). Thus, the argument establishes that some of the properties that are essential for something to be a microphysical systems are relational. Even if properties such as charge and mass are intrinsic, they are tied to relational properties; for nothing that does not have a position and a momentum can have charge or mass.

Nevertheless, one may envisage going further and maintain that state-independent properties such as charge and mass are in fact relational in some sense as well. An argument to that effect can pursue two strategies. Starting from the formalism of quantum mechanics, it is not satisfactory if one has to take up state-independent properties such as charge and mass as something given in addition to the state-dependent properties that are treated by that formalism. It would be desirable to derive these properties somehow from this formalism. The strategy to pursue in that respect is to refer to what are known as superselection rules. These are rules that introduce properties within the formalism of quantum mechanics that always have a definite numerical value and hence are not subject to entanglement. The idea thus is to get to state-independent properties such as charge and mass on the basis of properties that are relational in the sense described. Furthermore, independent of quantum mechanics, one may question whether properties such as charge and mass are really intrinsic. A point-like charge is embedded in a whole field; and taking into account considerations in connection with relativity physics, it is arguable that mass is a relational property as well (see, for instance, Teller 1991, sections VI–VII).

[329] V. From Quantum Mechanics to Quantum Field Theory

Quantum mechanics regards electrons and the like as physical systems that are subjects of the predication of properties and that persist. However, electrons and the like can be created and annihilated. If we look for a theory that treats the creation and annihilation of electrons and the like, we have to go into quantum field theory. Quantum field theory, therefore, is a more basic theory than quantum mechanics. When it comes to the concrete shape that physicalism might take, we have to consider quantum field theory – despite the fact that the philosophy of quantum field theory is in its infancy (see, in particular, the books by Auyang 1995, Teller 1995, and Cao 1997). Quantum field theory conceives one field for each kind of those entities that are treated as physical systems in quantum mechanics (such as electrons). What are regarded as single quantum systems in quantum mechanics are considered as field quanta in quantum field theory.

There is no fixed number of field quanta. The number of field quanta in a given state of a quantum field is an observable, which is represented by a field operator. This observable has all the features that are characteristic of an observable in quantum theory. In particular, there is no need for it to have one definite numerical value in every state. There are states of quantum fields that are superpositions of states with different numbers of field quanta. Field quanta, to which number operators apply, amount to a particle aspect in quantum field theory. But they cannot be considered as physical systems for which properties are predicated. (For a claim to the contrary, see van Fraassen 1991, Chapter 12; for a criticism of van Fraassen’s view, see Butterfield 1993, in particular 473–74.) The number of field quanta simply is the number of times a field state is occupied. Field quanta are excitations of quantum fields. It is therefore appropriate to regard field quanta as properties of quantum fields. Hence, what are considered as single physical systems in quantum mechanics are treated as properties of quantum fields in quantum field theory. Only a whole quantum field is a physical system for which properties are predicated.

What is the relevance of quantum field theory when it comes to the holism that is implicit in quantum physics? Let us come back to the space-time model that I introduced in section 3. In a first step, this model proposes to regard all physical properties as being realized as properties of space–time points or regions. In a second step, this model suggests treating the whole of space–time as the ultimate subject of predication; the properties that are predicated of the whole of space–time include an internal differentiation in the form of parts, that is, from regions down to points at which these property instantiations are localized.

As far as holism is concerned, the transition from quantum mechanics to quantum field theory can be compared to the transition from the first to the second step in this model. Owing to entanglement, ultimately only the whole of all quantum systems in quantum mechanics, like only the whole [330] of all quantum fields in quantum field theory, is in a pure state. Quantum mechanics starts with single physical systems, some properties of which turns out to be completely specified only by the state of the whole of all quantum systems taken together (so that these properties are, in fact, relational properties). In an ontology of quantum field theory, by contrast, we have nothing but the state of a quantum field – and in the final analysis the pure state of all quantum fields taken together – to start with. This latter pure state consists in properties being predicated of the whole of all quantum fields taken together. Nonetheless, this state expresses an internal structure: The properties of the whole specify local properties as described by field operators and determine correlations between these local properties. The plurality of single systems that are ultimate subjects of the predication of properties disappears in quantum field theory; nevertheless, the properties that are predicated of a quantum field as a whole include an internal differentiation within such a field.

In quantum field theory, the correlations to which entanglement in quantum mechanics gives rise are expressed as correlations between the conditional probability distributions of the values of field operators at space-time points (or point-like space-time regions). Given the outcome of a measurement of an operator at one space-time point, the probability for the outcome of a measurement of the same operator at a space-like separated point in the sense of special relativity can be changed. Such correlations occur even in the vacuum state (see, for instance, Redhead 1995). Note again that even if we interpret these probability distributions in terms of propensities, we are not committed to bare dispositions. It is the quantum state of the whole field that determines these distributions. There is no reason to regard that state itself as a disposition.

We can regard the probability distributions of the values of field operators at space–time points as parts of a quantum field, assuming an interpretation of quantum field theory in terms of objective probabilities. The properties of the whole field thus include something that can be considered as parts of a quantum field and correlations between these parts. These parts are dependent for their existence on the whole, because they are entirely determined through properties of the whole. Mermin (1998) maintains that quantum theory describes a world of correlations without presupposing underlying particulars as correlates. This idea makes good sense, I submit, if we do not assume free-floating correlations, but a quantum state of the world as that entity that gives rise to and determines these correlations (including an assumption of parts, in the sense of field operators at space–time points among which these correlations obtain).

Let us now go beyond what is achieved in current physics and consider what might be a plausible ontological consequence of a future development of physics. The aim of quantum field theory is to take all kinds of interaction into account. However, as far as gravitation is concerned, this aim has as yet not been achieved. We do not have at our disposal a unification of [331] quantum field theory with general relativity, which treats gravitation. Nonetheless, if we countenance in our ontology the notion of a global quantum state of the world, it is reasonable to conceive this state in such a way that it includes gravitation.

Furthermore, if we pay tribute to special relativity, we have to conceive this state as not developing in time, but as being defined over the whole of space–time. Last but not least, consider this point: An ontology that recognizes both space–time and matter (quantum fields) as different basic entities can with reason be taken to be prodigious. An ontology that shows that one of these is sufficient on the basic level would be more plausible. Because the program of geometrodynamics has failed, it is attractive to envisage trying the opposite program, namely, to get to a theory of space–time on the basis of a quantum field theory of matter. One may therefore go as far as envisaging building a theory of space-time on the basis of such a quantum ontology. (For an overview of different suggestions in that direction, see Monk 1997).

VI. Physicalism as Ontological Quantum Holism

Given the argument for an ontology along the lines of the described holism consequent upon quantum physics, what implications does such an ontology have for central themes of physicalism such as supervenience, realization of higher order properties by basic physical ones, and reduction? Consider what is perhaps the most prominent version of physicalism, David Lewis's thesis of Humean supervenience:

> It is the doctrine that all there is to the world is a vast mosaic of local matters of particular fact, just one little thing and then another. … We have geometry: a system of external relations of spatio-temporal distance between points. Maybe points of spacetime itself, maybe point-sized bits of matter or aether or fields, maybe both. And at those points we have local qualities: perfectly natural intrinsic properties which need nothing bigger than a point at which to be instantiated. For short: we have an arrangement of qualities. And that is all. There is no difference without difference in the arrangement of qualities. All else supervenes on that. (1986a, ix-x)

Lewis's thesis of Humean supervenience makes clear what is often seen as the concrete shape that physicalism might take: On the most basic level, the world is compartmentalized into local matters of particular fact, and everything else supervenes on these local matters. Nonetheless, Humean supervenience can be construed in such a way that it comes close to the space-time model of an ontological holism that I presented in section 3: Lewis (1986b) says that he personally favors an ontology that identifies matter with space-time (76 note). Such an identification can lead to a version of the described space-time model; the ontological status of space-time points would, however, have to be clarified. Be that as it may, if one [332] accepts quantum entanglement, one has to acknowledge a failure of Humean supervenience. Lewis himself says in a later paper:

> The point of defending Humean Supervenience is not to support reactionary physics, but rather to resist philosophical arguments that there are more things in heaven and earth than physics has dreamt of. Therefore if I defend the *philosophical* tenability of Humean Supervenience, that defence can doubtless be adapted to whatever better supervenience thesis may emerge from better physics. (1994, 474)

What is the supervenience thesis that may emerge from quantum physics? Humean supervenience takes global features of the world to supervene on local ones, that is, the distribution of intrinsic properties at space-time points, given a grid of relations of spatio-temporal distance between points that unifies a world. But Humean supervenience is a thesis of global supervenience in the sense that it is formulated in terms of a comparison between whole possible worlds; two worlds that have the same distribution of intrinsic properties at space-time points are identical in all respects. (One can turn Humean supervenience into a contingent thesis by introducing suitable qualifications in the worlds to which it applies; see Lewis 1986a, x.) We can take up this latter point, that is, global supervenience, but we have to change Lewis's conception of the supervenience basis in order to accommodate quantum physics.

The holism that issues from quantum physics has the following impact on our view of nature: A position such as Humean supervenience has to be replaced with, ontologically speaking, a position that starts from features that are properties of matter as a whole on the quantum level. We have to include the state of the whole of all quantum systems or, better, all quantum fields, as a global feature in the supervenience basis. Quantum physics thus requires a reversal of perspective: We cannot work from one local matter of particular fact to the next local matter of particular fact via spatio-temporal relations. Instead, we have to start in our ontology with the notion of the global state of all quantum systems taken together; this state then determines local matters of particular fact. Nonetheless, nothing hinders us from positing that everything in a world like ours supervenes on that state.

Many physicalists have reservations about committing themselves to Lewis's Humean supervenience. Pettit, for instance, contemplates the possibility "that certain relational, microphysical properties – apart from spatio-temporal properties – are in some way fundamental" (1993, 215). He adds "that the microphysicalist can keep the supervenience aspect of Lewis's picture – can maintain his microphysicalism – while dropping the Humean one" (1993, 215, note 2; see also Jackson 1998, 6–8). The proposal advanced here is a suggestion for a concrete elaboration of this idea that takes quantum physics into account.

[333] One can argue that global supervenience alone is too weak to define physicalism. It is common to conceive physicalism as the conjunction of the theses that (1) everything supervenes on some physical basis and that (2) everything is realized as some sort of a physical arrangement (see, for instance, Papineau 1993, Chapter 1, in particular 12). Let us therefore briefly turn to physical realization. According to the proposed ontological impact of quantum physics, we cannot conceive higher-order properties in such a way that they are realized as an arrangement of point-like particles, which are characterized by intrinsic properties each, or as an arrangement of intrinsic properties of space-time points. Instead, we have to conceive them as being realized as a pattern within a quantum field. Regarding, say, a table (the property of being a table), as being realized as a pattern in a quantum field poses in principle no more – and no fewer – conceptual difficulties than regarding a table as being realized as an arrangement of atoms or as a distribution of basic intrinsic properties at space–time points. I cannot address these difficulties here, for they concern the defense of physicalism as based on microphysics in general, whatever the concrete shape of microphysics might be.

Nonetheless, one issue has to be addressed here: The point that attracts the most attention in the philosophy of quantum physics is not entanglement as such, but the so-called measurement problem, which is a consequence of entanglement. The measurement problem is the question of how we can square quantum entanglement with our experience of macroscopic properties that always have a definite numerical value each. (For a comprehensive recent treatment of the measurement problem, see Mittelstaedt 1998.) There are two principal options as regards the measurement problem. These options have an impact on the way in which a physicalism on the basis of quantum physics is spelled out in concrete terms.

The more radical option is to say that macroscopic properties up to mental properties are not what we take them to be; in fact, entanglement extends to all properties. It only appears to us that there are macroscopic properties that always have one definite numerical value and that are thus not subject to entanglement. It is possible to explain this appearance within this interpretation of quantum physics. As Lockwood (1989) has shown, this option can be developed within the framework of physicalism. Thus, coming back to my formulation above, according to this option, higher-order properties are realized as patterns in a quantum field in such a way that they are themselves subject to what is characteristic of such a field, that is, entanglement.

The more conservative option is to say that when it comes to the transition to higher-order properties, a dissolution of entanglement occurs, so that there can be higher-order properties in the way in which we experience them. The problem with this option is that it implies that a dissolution of entanglement, known as state reduction, occurs at least locally at the quantum level as well, for macroscopic properties have a microphysical realization. [334] However, we have as yet no overall convincing account at our disposal how a dissolution of entanglement can occur within the scope of quantum theory.

Furthermore, it may seem that this option clashes with the claim of physicalism as ontological holism based on quantum theory. For if we endorse this option, we maintain that state reductions, and hence, cases of disentanglement, occur at least locally on the quantum level. But this clash is only apparent; for the crucial point is this: In a reconstruction of the transition to higher-order properties and state reductions on the quantum level, we have to start with considering matter as one holistic system at the microphysical level if we use quantum theory as a basis. Only if we first assume that there is ubiquitous entanglement on the quantum level can we subsequently develop more and more higher order properties that are not subject to entanglement; and only on that basis can state reductions occur on the quantum level. If we accept quantum theory as the theory of the microphysical level, what is to be explained is not entanglement, but the failure of entanglement.

One can claim that the ontological theses of supervenience and microphysical realization are not sufficient for physicalism; the epistemological program of a reduction of higher-level theories to a basic physical theory also is necessary for physicalism (see, for instance, Francescotti 1998). My point is that, as in the case of supervenience claims, quantum entanglement requires us to change our conception of the basis for reduction, that is, our conception of the basic physical theory to which other theories are to be reduced. But a basic physical theory, however odd it conceptual features may seem, as such neither excludes higher level theories nor implies that higher level theories can be reduced to it. The program of reductionism is not challenged even if one endorses what I have described in the preceding paragraphs as the more conservative option. Prominent proposals for an account of state reductions and thus disentanglement – such as that of Ghiradi, Rimini and Weber (1986) and that of Penrose (1994, Chapter 6, §§ 10–12), which includes gravitation – certainly do not exclude the possibility of a reduction of higher level theories to quantum theory. Nonetheless, a judgment on whether or not such a reduction can in fact be carried out is premature; we need first a detailed and satisfactory theory of the physical process of a dissolution of entanglement. Consider the classical view of reduction of Nagel (1961, Chapter 11). Once we have a quantum theory at our disposal that includes a satisfactory account of a dissolution of entanglement, it may be possible to translate the concepts of higher-order theories into the concepts of such a quantum theory and to deduce the laws of higher-order theories from the laws of such a quantum theory by means of bridging principles. (As to reduction and quantum theory, compare Scheibe 1997/99, Vol. 2, Chapter X.)

The main claim of this paper is independent of whatever stance one may take on these controversial issues in the interpretation of quantum physics: [335] When it comes to a concrete formulation of physicalism, we have to take quantum physics into account. Quantum physics suggests that we have to conceive physicalism as ontological holism – in the sense that ultimately, the global quantum state of the world that determines what there is.

To conclude, note that there is a certain irony in the story I have told: Analytic philosophy starts with Russell and Moore at the beginning of this century rejecting the claims of Bradley in particular, thereby attacking that minority stream in Western philosophy that is favorable to an ontological holism. Nonetheless, at the end of this century, analytic philosophy may make available an ontology that is somewhat similar to the one of Bradley (1920; see, in particular, Chapter 13) – namely, an ontology of a holism that acknowledges in the end only one being, the global quantum state of the world. But note (1) the internal, physical structure of this state and (2) the arguments for this position, which come from science and not from logic and metaphysics. This ontological holism does not amount to any sort of an idealism, being instead the concrete shape which a physicalism that bases itself on contemporary physics should take.

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