The World as we Know It

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Abstract

Albert Einstein thought of physics as the search for the order and harmony of the world—a harmony he spoke of in quasi-religious terms. In his theories of relativity he succeeded brilliantly in discerning a hidden unity in nature. But by pursuing his unfinished quest for a unified field theory he abandoned the mainstream of research that was increasingly dominated by the quantum theory he had helped to found, but whose foundations he continued to question. That research has now produced a (partially) unified physics based on quantum field theory. But the ontology of quantum field theory remains opaque. This paper will motivate and explore the radical proposal that quantum field theory describes a single, non-composite object—the World, and that everything else (elementary particles, chairs, people, planets, space-time) arises as an aspect of the World's enormously rich structure.

1. Introduction

In his fourth lecture on pragmatism, William James asked his audience to bear with him while he tried to inspire them with his interest in what he considered the most central of all philosophical problems—the ancient problem of the one and the many. More than a century after the rise of analytic philosophy, few are likely to endorse James's positioning of this problem. From their vantage point in the thick of one contemporary debate or another, many philosophers may well view the present collection of essays on monism as an expedition into a musty intellectual attic of abandoned doctrines, a quixotic attempt by analytic metaphysicians to justify the existence of their discipline by attempting to revive a dead dispute, or both. A due respect for science would seem to require a pluralist ontology that at least includes such fundamental entities as electrons and quarks—not to mention atoms, molecules, neurons and stem cells. Even instrumentalists and constructive empiricists are committed to a plurality of eyes, ears, brains, bodies, microscopes and (so-called!) particle accelerators. As he points out, simply acknowledging with Moore that one has two hands already appears to establish what Schaffer(2007) calls existence pluralism—the view that there is more than one concrete object.

Nevertheless, one can trace a line of thought from Einstein back to Spinoza and forward to our currently best fundamental physics that provides the materials for a scientifically-based argument for existence monism. If this argument were to succeed, it might be taken to supplement Horgan and Potrč's(2008) semantic argument for that thesis. Though fascinating, I believe the argument fails. Moreover, the reasons for its failure cast doubt on Horgan and Potrč's semantic argument. In the end, contemporary physics does not furnish us with a good argument for existence monism. In an ironic twist, it rather furnishes us with an argument for a Jamesian pluralism.

After this brief introduction, the paper begins by locating Einstein's thought in relation to Spinoza's philosophy as well as the history of twentieth century physics. It is well known that in his later years, Einstein often alluded to Spinoza when expressing his attitude to life and work. What is less often appreciated is that the (unsuccessful) research into a unified field theory on which Einstein was then engaged could be seen as an attempt to create a theory of nature that would have accorded well with Spinoza's metaphysics—at least as interpreted by one recent commentator (Jonathan Bennett). What increasingly set Einstein apart from the mainstream of physics was his unorthodox view of quantum theory and unwillingness to acknowledge its fundamental status within physics. Years after Einstein's death, progress in physics led to the development of what is known as the Standard Model. Because of its successful unification of fields responsible for fundamental forces, this has sometimes been touted as at least the partial realization of Einstein's dream of a unified field theory. But these are not classical but *quantum* fields—a crucial difference for the issue of monism (or so I shall argue).

In section 3 I explain alternative ways of understanding the ontology of a classical field. On one understanding, a unified *classical* field theory of the kind Einstein unsuccessfully sought would have provided a scientific basis for an argument for existence monism.

But the partial unification of fundamental interactions in the Standard Model has been achieved not by classical but by quantum field theories, whose features are sufficiently different as to rule out any simple extension or analog of this argument. Section 4 explains why it is so hard to provide *any* ontology for a quantum field theory—any account of what such a theory might be taken to describe or represent.

Section 5 explores the idea of a radically monist ontology for the interacting quantum fields of the Standard Model and a possibly more unified successor theory. At first sight this may seem to provide the basis for an argument from fundamental physics to a monism like that advocated on very different grounds by Horgan and Potrč. But on closer examination this argument fails because it rests on an equivocal use of the term 'fundamental'.

Clarifying the usage of this term reveals a tension between this scientifically-based argument and the semantics underlying Horgan and Potrč's argument for monism. Section 6 argues that replacing their contextual but still representationally-based semantics by an inferentialist alternative makes it possible to combine a non-pluralist ontology *for fundamental physical theory* with a whole-hearted acceptance of a plurality of quarks, electrons and other scientific as well as ordinary objects. I think the resulting resolution of this dispute between monism and pluralism would gladden the heart of a reconciliatory pragmatist like James.

2. Historical Background

Einstein read and was influenced by the work of several philosophers, including Hume, Kant and Mach. But it was only Spinoza whom he regarded with reverence, referring to him in correspondence as "our master Spinoza, who was the first" and even writing a poem entitled "For Spinoza's *Ethics*" which begins "How much do I love that noble man, more than I could tell with words". Such reverence stems more from Einstein's identification with the life and ideals of Spinoza than from endorsement of his philosophy, of whose details Einstein repeatedly claimed ignorance. As Paty(1986) says

> If we want to give meaning to such a question as *to what extent is Einstein's thought Spinozistic?* we must understand 'Spinozistic' not as a model, a system, or even a tradition, but as a way of being, as a thinker, in the world. (270)

But Einstein had good reasons to think he shared some of his deepest beliefs with Spinoza, as when he famously said

> I believe in Spinoza's God, who reveals Himself in the orderly harmony of what exists, not in a God who concerns Himself with fates and actions of human beings.[1]

Einstein wrote of this same God in the letter to Max Born which included the famous passage

> Quantum mechanics is certainly imposing. But an inner voice tells me that it is not yet the real thing. The theory says a lot, but does not really bring us closer to the secret of the 'old one'. I, at any rate, am convinced that *He* is not playing at dice.[2]

Here Einstein gives voice to a commitment to determinism that he also shared with Spinoza, and which he viewed not as a limitation on human freedom and creativity, but rather as a way of reconciling oneself to the apparent evil and stupidity of human actions. He made that shared commitment explicit in a letter answering a question of a Brooklyn Rabbi:

> I share exactly Spinoza's opinion and...as a convinced determinist, I have no sympathy at all for the monotheist conceptions.[3]

Einstein recognized Spinoza as a fellow spirit because he shared his intense desire to understand the unity of what the latter referred to as *Deus sive Natura* as a way of transcending the merely personal and attaining the "Joy in looking and comprehending [that] is nature's most beautiful gift".[4] That is what motivated him to say to a young student (Esther Salaman)

> I want to know how God created this world. I'm not interested in this or that phenomenon, in the spectrum of this or that element. I want to know His thoughts, the rest are details.[5]

Of course, Einstein's fame rests on his scientific achievements and not on the opinions on non-scientific subjects solicited from him in consequence. In turning now to Einstein's work as a physicist, it is important not to over-interpret the influence of these opinions on his physics. Nevertheless, the search for unity in nature, and at least a preference for seeking such unity in a deterministic physics, did characterize Einstein's approach to research in physics, successful as well as unsuccessful. His theory of special relativity enabled us to see space and time as different aspects of a single space-time, while electric and magnetic fields are different aspects of a single electromagnetic field. The general theory of relativity subsequently knitted geometry to gravity, now understood both as space-time curvature and as a four-dimensional gravitational field. But in its original formulation it could not be considered a unified theory of all physical phenomena, for several reasons. One reason stemmed from the need separately to postulate a geodesic law of motion for material particles. Einstein himself took the first step to remove this element of disunity by deriving this law from the field equations themselves, treating a material particle as a singularity of the gravitational field. A second reason stemmed from the fact that the field

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[1] *The New York Times*, April 25th, 1929, p.60, col.4.

[2] In *The Born-Einstein Letters* (Born(1971), 91).

[3] Letter to Rabbi A. Geller, September 4th, 1930, Einstein Archives, unpublished.

[4] Einstein(1954a), 28.

[5] E. Salaman, "A Talk with Einstein," *The Listener 54* (1955), 370-371.

equations include a schematic term (the stress-energy tensor) associated with non-gravitational matter of a kind that must be independently specified.[6] A more unified theory would replace this schema by a tensor associated with some specific matter field—if not the electromagnetic field tensor, then some suitably unified generalization representing *all* non-gravitational matter. Einstein(1949, 89-94) explained how he hoped to remedy this defect in the unified field theory on which he worked without success for many years toward the end of his life, effectively isolating himself from the mainstream of research in physics. But the most important barrier to Einstein's quest for the unification of physics came from developments in that mainstream itself.

On the one hand, experiments had revealed new short-range fundamental forces associated with nuclear and sub-nuclear phenomena (corresponding to the so-called weak and strong interactions) that would also somehow need to be incorporated into a unified physics. On the other hand, the quantum theory to whose development Einstein had made significant early contributions (notably including the 1905 paper cited in the award of his Nobel prize) came to be applied with great success to an increasingly wide range of phenomena. Einstein certainly recognized this as an enormous advance, and did not reject the quantum theory that made it possible. But he viewed quantum theory from an unorthodox perspective from which it could not be seen as the kind of fundamental theory he continued to seek. Since his view is still widely misunderstood, it may be worth spending some time to explain Einstein's attitude toward quantum theory.

This is based on his conception of the task of physics, which he states as follows.

> Physics is an attempt conceptually to grasp reality as it is thought independently of its being observed. In this sense one speaks of "physical reality". In pre-quantum physics there was no doubt as to how this was to be understood. ... In quantum mechanics it is not so easily seen. If one asks: does a ψ-function of the quantum theory represent a real factual situation in the same sense in which this is the case of a material system of points or of an electromagnetic field, one hesitates to reply with a simple "yes" or "no". (Einstein(1949), 82-3)

Einstein (here as elsewhere) went on to argue that the ψ-function does *not* constitute a complete description of a real factual situation, and continued (p.87)

> The statistical character of the present theory would then have to be a necessary consequence of the incompleteness of the description of the systems in quantum mechanics, and there would no longer exist any ground for the supposition that a future basis of physics must be based on statistics. – – –
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> It is my opinion that the contemporary quantum theory by means of certain definitely laid down basic concepts, which on the whole have been taken over from classical mechanics, constitutes an optimum formulation of the connections. I believe, however, that this theory offers no useful point of departure for future development.

He further elaborates in his "Reply to Criticisms" in the same work (p.672).

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[6] Einstein(1936, 370) likened the stress-energy tensor associated with non-gravitational matter on the right-hand side of his field equations to low grade wood, in contrast to the "fine marble" of the Einstein tensor associated with the gravitational field on their left-hand side.

> Assuming the success of efforts to accomplish a complete physical description, the statistical quantum theory would, within the framework of future physics, take an approximately analogous position to the statistical mechanics within the framework of classical mechanics. I am rather firmly convinced that the development of theoretical physics will be of this type; but the path will be lengthy and difficult.

Einstein did not reject quantum theory because of his commitment to determinism ("God does not play dice"). He simply denied that it could be a fundamental theory, because he insisted that physics provide a description of reality, and he thought he had arguments proving that quantum theory cannot completely describe a physical situation. The unified field theory he sought would have provided the complete description required of any fundamental theory, and might (but perhaps need not) have done so in such a way as to restore determinism. In the light of this theory, quantum probabilities could then be seen to be merely epistemic, just like those of classical statistical mechanics.

Theoretical physics has not progressed along the path Einstein foretold in 1949, but along a different path. While his theory of general relativity remains our best theory of gravity, having withstood severe observational tests, this theory stubbornly resists attempts to unify it with other fundamental interactions—electromagnetic, weak and nuclear. These attempts are now understood to require a quantum theory of gravity, largely because our best theories of fundamental non-gravitational interactions are quantum theories, and since the 1970's these *have* been to a large extent unified in the so-called Standard Model. Contrary to Einstein's conviction, and despite his scruples, there is a widespread belief today that any plausible candidate for a unified fundamental theory (a "Theory of Everything") would be a quantum theory.

The experimentally successful Standard Model incorporates quantum field theories characterizing two ways in which matter can interact: quantum chromodynamics (for the strong interaction) and unified electro-weak theory (for the electromagnetic and weak interactions). Attempts to further unify these interactions into a so-called grand unified theory (GUT) have so far not proved experimentally successful. Many physicists believe that superstring theory (or its generalization, *M*-theory) hold the best prospects for a successful unified theory, of not only strong and electro-weak interactions, but also gravity. But in so far as any such theory is a quantum theory, it would not constitute a unified field theory of a kind that Einstein could have considered fundamental: he would have taken it to offer us, at best, a pointer along the path to such a theory.

Now while Einstein was firmly convinced that theoretical physics would follow the path on which he himself set out, he stressed that this path would be lengthy and difficult. Perhaps centuries hence physicists will look upon our present infatuation with quantum theory as a temporary detour from that path—necessary, perhaps, to reach a vantage point from which to get a better view of the way ahead? Even if Einstein's conviction proves unfounded, it is interesting to ask how well a classical, unified field theory of the kind Einstein sought would have squared with Spinoza's metaphysics. If one follows Bennett's(1984; 1991) interpretation of his metaphysics, I think the answer is "remarkably well".

Bennett takes Spinoza to adopt a field metaphysics in his *Ethics*. This enables him to reconcile his claim that there is only one substance (*Deus sive Natura*) with the plurality of concrete objects we take ourselves to experience in the world (each other, sticks, tables, planets,...). Bennett typically refers to this one substance as space—God/Nature under the attribute of extension. His Spinoza takes a planet (for example) to consist in a complex feature (a "mode") of space, so that its "existence" consists of space's exhibiting a continuous sequence of closely related physical properties *planetary-trajectory-wise* (as it were, on a spatio-temporally continuous sequence of space-time points strung along its trajectory—except that, since there are no such space-time points, the italicized phrase must be understood as an adverbial modification of each property). It is but a little stretch to take the one substance to be space-time rather than space. Indeed, that modification would give Spinoza a deep reason to explain why God is eternal and unchanging—it makes no sense to suppose that *space-time* changes.

So modified, one can take Einstein's search for a unified field theory as an attempt to realize Spinoza's metaphysics of Nature. Einstein(1954) himself likened the space-time of general relativity to Descartes' space

> There is no such thing as an empty space, i.e. a space without a field. Spacetime does not claim existence on its own, but only as a structural quality of the field.
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> Thus Descartes was not so far from the truth when he believed he must exclude the existence of an empty space. The notion indeed appears absurd, as long as physical reality is seen exclusively in ponderable bodies. It requires the idea of the field as the representative of reality, in combination with the general principle of relativity, to show the true kernel of Descartes' idea; there exists no space "empty of field." (155-6)

An Einsteinian unified field would be a remarkably unified Spinozan *Natura*, at least in its attribute of extension. Not only space-time, but every concrete "thing" would emerge as "a structural quality of the field"—the one true substance. Given Einstein's awe of nature and denial of a personal God, one can even see Einstein as thinking of the unified field as a Spinozan *Deus*, under the attribute of thought!

3. Classical Field Theory and Existence Monism

Quite apart from the historical context, one can raise the question as to whether an Einsteinian unified field theory would have vindicated existence monism—the view that there is exactly one concrete object. Is there a good argument for existence monism based on such a classical field theory? To address this question it is first necessary to clarify the notion, and especially the ontology, of a classical field theory.

What is a classical field? A particular classical field configuration represents an assignment of a numerical value to each of one or more related field magnitudes at every space-time point. A classical field theory includes field equations that specify the physically possible field configurations as those in which the values assigned at different points are appropriately related to one another.

Classical electro-statistics provides a simple example of a field theory. The electric potential $\varphi(\boldsymbol{r},t)$ is a function that assigns a real number (a so-called scalar) to each point $\boldsymbol{r}$ of space at each instant t (indeed, the same number for every instant—which is why it's called electro-statics!) The electric field $\boldsymbol{E}(\boldsymbol{r},t)$ then equals the gradient of φ—it is a vector field that determines the rate of change of the electric potential in any arbitrary direction in space. A charged particle with charge q placed at $\boldsymbol{r}$ will experience a force $\boldsymbol{F}=q\boldsymbol{E}$, whose effects on its motion can be directly observed, thereby indirectly manifesting the electric field that is responsible for this force. Both $\boldsymbol{E}$ and φ count as classical fields, as I have explained that notion.

What can we conclude about the ontology of a classical field theory? First consider a scalar field *f*. Here is one possible ontological analysis. Corresponding to each real number *x* in the range of *f* there is a property P_x: to say that $f(\boldsymbol{r},t)=x$ is just to say that space-time point $\boldsymbol{r},t$ has property P_x. Taken at face value, this analysis commits one to an ontology of space-time points (labeled by) $\boldsymbol{r},t$ and an ideology (in Quine's sense) of determinate properties of the form P_x associated with the determinable magnitude $f(\boldsymbol{r},t)$.[7] An ontology of space-time points is acceptable to a space-time substantivalist, and Hartry Field(1986) for one took this analysis of fields as presenting a challenge to a relationist opponent.

The analysis of vector fields like $\boldsymbol{E}$ is trickier, because these involve spatial directions as well as scalar magnitudes. But the underlying ontology is still one of space-time points. Even if the analysis of vector magnitudes requires the attribution of relations between them, the points concerned will be arbitrarily close together, in conformity to the guiding intuition that everything supervenes on local matters of fact. Moreover, if a vector field like $\boldsymbol{E}$ were itself to supervene on an underlying scalar field like φ, then no modification would be needed.

But here an interesting issue arises. According to the theory of electrostatics, all observable effects of φ are "filtered through" the action of $\boldsymbol{E}$ on charged particles. Distinct scalar potentials φ_1,φ_2 correspond to the same electric field $\boldsymbol{E}$ if they differ by a constant: $\varphi_1=\varphi_2+C$. It follows from the theory that no observation or measurement can distinguish between electric potentials that differ in just this way. It is not just verificationists who will take this fact to warrant skepticism about the ontological credentials of the scalar field φ.

The magnetic field $\boldsymbol{B}$ of classical electromagnetic theory is similarly related to a vector potential $\boldsymbol{A}$, but in this case the range of distinct magnetic potentials $\boldsymbol{A}$ corresponding to a single magnetic field $\boldsymbol{B}$ is far greater: a transformation from one to another is called a gauge transformation.

The full theory of classical electromagnetism portrays electric and magnetic fields as just different aspects of a single electromagnetic field *F*. This field is associated with an electromagnetic potential *A*: each of $\varphi,\boldsymbol{A}$ represents a different aspect of *A*. Again, a transformation between distinct electromagnetic potentials A_1,A_2 corresponding to the same electromagnetic field *F* is called a gauge transformation, and potentials related in this way are said to be gauge-equivalent. In purely classical physics, gauge-equivalent potentials are generally regarded as merely alternative ways of representing the same physical situation, which may be represented more directly by the one electromagnetic field *F* to which they correspond.

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[7] Carnap(1956;1966) did not take such an analysis at face value. As Friedman(forthcoming) explains, he proposed to dissolve the dispute between realist and instrumentalist about the reference of theoretical terms such as those purportedly denoting classical fields. Roughly, his proposal was to regard a scalar field *f* as a purely mathematical function from quadruples of real numbers $\boldsymbol{r},t$ (*not* "concrete" space-time points these label!) into the real numbers. The ontological question was then to be replaced by the question as to whether or not to use a language including such a theoretical term for the purposes of physics—a question to be answered on purely pragmatic grounds.

But when classical electromagnetism is married to quantum particle mechanics, phenomena arise which have prompted physicists to re-examine this instrumentalist attitude toward electromagnetic potentials. Effects are observed that seem to show that there is more to classical electromagnetism than can be represented by the F field alone. And yet the gauge symmetry of this combined gauge theory implies that these phenomena still provide no way for measurements to discriminate among distinct electromagnetic potentials A_1,A_2 related by a gauge transformation!

There is a way of resolving this puzzling situation, and it has some interesting metaphysical implications. To each smooth closed loop in space-time there corresponds a magnitude called the holonomy of that loop. Like the values of the electromagnetic field F, the values of all holonomies are independent of which of a gauge-equivalent class of potentials A is chosen to compute them. But the holonomies of all closed curves in a region do not supervene on the values of the electromagnetic field F at points in that region. It is natural to take the value of the holonomy of a loop to represent a physical property of that loop. For such properties provide the basis for a unified and predictively accurate account of otherwise puzzling electromagnetic phenomena. Detailed observations of such phenomena would provide a way to measure the values of holonomies of loops in regions where the phenomena occur. But the potential A remains unmeasurable, and the same ontological scruples continue to favor an instrumentalist attitude toward it.[8]

The success of this application of classical electromagnetism when married to the quantum mechanics of particles provides a strong reason to countenance holistic properties–specifically, properties of closed loops in space-time that do not supervene on properties of their constituent space-time points. Moreover, some of these loops must be macroscopic to explain observed phenomena. Although acceptance of holistic properties remains consistent with an ontology of space-time points, the resultant ideology is in radical contradiction to Humean supervenience.

Before moving on to consider the ontology of quantum field theories, let me suggest an alternative analysis of purely classical fields whose acceptance would threaten an ontology of space-time points. I think that we can arrive at it by a somewhat surprising extension of a familiar metaphysical view.

This is the view that objects persist by enduring rather than perduring (to adopt David Lewis's terminology). While a perduring object persists in virtue of the relations obtaining among its various temporal parts, an enduring object persists even though it has no temporal parts, since it is wholly present at each moment of its existence.

To extend this view to fields, consider a field as something that is wholly present at each moment and at each place of its existence. A fundamental field like gravity or electromagnetism is something which is wholly present everywhere and at all times, or better, wholly present at every space-time point. In accordance with Einstein's(1954) view, by such omnipresence a classical field constitutes space-time. On this view, a field is an ontologically primitive entity. But space-time points and regions need not be accepted as objects at all. On an adverbial version of the view along the lines of Bennett's Spinoza, one can regard them rather as spatio-temporal ways for a field to possess properties such as a particular electromagnetic field strength.

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[8] For further details, see Healey(2007).

On this understanding of the ontology of classical fields, a successful Einsteinian fundamental physics would require only a single concrete object—the unified field itself. This would then ground the following argument for existence monism.[9]

(1) The unified field is the only concrete object needed to understand the structure and evolution of the world.
(2) If the unified field is the only concrete object needed to understand the structure and evolution of the world, then any other concrete objects would be explanatorily redundant or epiphenomenal entities.
(3) There are no explanatorily redundant or epiphenomenal entities.
(4) The unified field—the world—is the only concrete object.

Premise (1) is based on the assumed explanatory success of a classical, Einsteinian unified field theory. The understanding is provided by the (hypothetical) field equations, whose solution governs how the properties of the field are spatio-temporally distributed—or rather what are the spatio-temporally modified properties of the unified field (since spatio-temporality is now to be understood in terms of adverbial modifications of a property of the field, not in terms of field properties of or at space-time locations). This argument may be criticized on various grounds (cf. Schaffer(2007)), but I think it will hold a powerful appeal for one who shares Einstein's vision of a harmonious and unified Nature whose details, though present, have no grounding in features of a miscellany of independently existing concrete objects.

4. The Problematic Ontology of Quantum Field Theories

In a typical formulation, a quantum field is represented by an assignment of one or more related *operators* to every space-time point. A quantum field theory includes field equations that specify how the operators assigned at different points are appropriately related to one another. A field operator is a mathematical object that maps vectors in an abstract vector space onto one another. The state of a system is specified by a vector from this space, and not by a particular assignment of field operators to space-time points. Neither the quantum field nor the state vector assigns numerical values to magnitudes defined at each space-time point. Rather, in combination they specify the expected value of each observable magnitude—the average value one would expect to get if one were to perform repeated measurements of that magnitude in that state. (Given the probabilistic nature of the theory, such measurements would generally not be expected to give the same result on every occasion.) Some of these magnitudes are local—they pertain to restricted space-time regions: others are global—they concern the field as a whole, without reference to any space-time region.

It follows that an assignment of expectation values to local magnitudes in a quantum field theory is quite different from an assignment of a numerical value at every space-time point to each independent magnitude of a classical field theory. But suppose that the state of a quantum field is represented by a vector for which the theory predicts that a measurement of magnitude M will give result m with probability 1. It is tempting to claim that M has value m in that state, which is then called an eigenstate of M with eigenvalue m. This claim is called the eigenvalue-eigenstate

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[9] This is a suitably modified version of a similar argument of Schaffer(2007).

link, and it plays a role in attempts to interpret quantum field theory as describing the behavior of particles.

One can construct a quantum theory of an electron field aimed at describing the behavior of hypothetical free electrons—electrons assumed not to be subject to electromagnetic or other interactions. The space of state vectors in this theory may be constructed by taking all linear combinations of certain basis vectors. Each of these basis vectors is an eigenstate of so-called number operators $\mathcal{N}_k$, themselves constructed from the basic quantum field operator. Each $\mathcal{N}_k$ has integer eigenvalues, so a basis state $|\ \rangle$ may be labeled by the set of these values $|n_1,n_2,...\rangle$: this is called the occupation number representation. The state of the field in which all these numbers are zero is called the vacuum state: it is the lowest energy state of the field. Applying the eigenvalue-eigenstate link, an excited eigenstate of $\mathcal{N}_k$ with eigenvalue n_k is taken to contain n_k field quanta of kind *k*. (n_k =0,1 in this case, since electrons are represented by a fermionic field. This is how the theory represents the famous Pauli exclusion principle, which applies also to other fermions, including quarks. n_k =0,1,2,... for photons or other bosons represented by a bosonic field.) The total number of quanta in a basis state is then the sum $n = n_1+n_2+...$ of all the n_k.

By identifying these quanta with particles (e.g. electrons), one can try to interpret $|n_1,n_2,...\rangle$ as a state in which there are n_1 electrons with feature 1, n_2 electrons with feature 2, etc. (where the feature is, for example, having a certain momentum). In favor of this interpretation, the total momentum and energy of the field each arises naturally as the sum or integral of the corresponding values for the individual quanta. But the interpretation faces serious problems.

First, these quanta cannot be localized in space—there is no well-behaved position operator whose eigenstates could be interpreted as states in which a single particle is present at a specific location.

Second, two distinct quanta with the same features in a basis state seem indiscernible and cannot be distinguished by their properties, apparently making it hard to reconcile their individual existence with empirically confirmed statistics of states supposedly containing large numbers of particles.

Third, the particle interpretation does not extend easily to an interpretation of states other than the basis states of the occupation number representation. A generic linear combination of basis states is a state that resists any natural particle interpretation—for example, how many particles are present in a superposition of a 3-particle basis state and a 17-particle basis state? Interpreting superpositions is always problematic in quantum mechanics, but here the problem strikes at the heart of a particle interpretation.

Fourth, there are situations in which the state of a quantum field may be represented in two quite different ways, leading to two completely different interpretations of its particle content. For example, a situation in which no particles are present in the standard representation (the Minkowski vacuum) may have a non-standard representation in which an indefinitely large number of particles are present (the so-called Rindler particles, which would indeed be detected by a uniformly accelerated observer).

These four problems already afflict a particle interpretation of a quantum field theory supposedly describing the behavior of hypothetical free electrons. But real electrons are never free. Because of their electric charge, they are subject to electromagnetic interactions.

Taking stable atomic matter to be composed of fermions—electrons and the quark constituents of the nucleus—fermionic fields are regarded as matter fields. But ordinary matter is held together by interactions (“forces”—though this term now functions more as a metaphor than a literal description of these interactions). While electrons are bound to the nucleus by the electromagnetic interaction, it is the strong interaction between quarks that holds the nucleus together despite electrical repulsions among its constituents. A free bosonic field represents bosons such as the photons associated with electromagnetic radiation.

There is a prescription for combining free fermionic and bosonic fields in the Standard Model, and their combination is taken to represent the interactions between fermions. These interactions are often said to be mediated by exchange of bosons of the corresponding bosonic field. Photons mediate the electromagnetic interaction, while gluons mediate the strong interaction.

Extending the already problematic particle interpretation of a free quantum field to cover interacting fields raises yet more problems! As Fraser(2008) explains, the mathematics of interaction blocks even the initial interpretative moves that gave plausibility to a particle interpretation of free quantum fields. Suffice it to say that no description of how properties of particles like electrons or *W* and *Z* bosons change during an interaction is forthcoming from quantum field theory.

We have seen that quantum field theory appears incompatible with a field ontology that requires assignment of numerical values to physical magnitudes at space-time points: rather, a quantum field assigns *operators* at space-time points. An alternative way to connect quantum to classical fields focuses instead on the elements of the space on which such operators act. The idea is to take elements of this space to be neither abstract vectors nor wave-functions (as in quantum mechanics) but wave-function*al*s, i.e. functions of classical field configurations over space-time. But Baker(2009) shows how the arguments of Fraser(2008) against particle interpretations of quantum field theory may be extended so as to exclude this kind of field interpretation of quantum field theory. Is there some other ontological account of a quantum field theory? I will briefly mention four proposals, only to dismiss them and pass on.

In her interesting book *How Is Quantum Field Theory Possible?* Auyang(1995) proposes an event ontology for a system of interacting quantum fields. These are supposedly spatio-temporally local events constituted by local field operators at each space-time point. The space-time points are not ontologically basic, but are rather themselves abstracted from the events, as their qualities or modes of occurrence. Unfortunately, the character of these supposed events remains quite unclear, and she offers no account of our epistemic access to them. Dennis Dieks(2000) has proposed an alternative event ontology which is problematic for other reasons.

Andrew Wayne(2002) has suggested that a quantum field should be understood as an ascription of a hierarchy of external relations to space-time points: unary, binary, ternary, *n*-ary, for all *n*. He relies on a theorem of Wightman which states that a quantum field is completely characterized by the vacuum expectation values (VEVs) of all *n*-fold products of field operators, each pertaining to a space-time point (making *n* possibly distinct points in all). At first sight, this appears to yield an ontology radically at variance with Humean supervenience, since it would involve non-spatiotemporal external relations among arbitrarily many space-time points, no matter how far apart. But on closer inspection it is not clear that the VEV interpretation has given us an ontology for a quantum field theory. For an expectation value merely represents the expected average of a sequence of measurements, none of which can be thought merely to reveal the pre-existing value of a magnitude defined at (one or more) space-time points.

A fourth proposal for an ontology for quantum field theory deserves more extended consideration. It has been made by those following David Bohm in his attempt to extend his famous “hidden variable theory”of quantum mechanics to quantum field theory.

One way of realizing the state vector of a system is by a wave-function $\psi(\boldsymbol{r}_1,\boldsymbol{r}_2,..\boldsymbol{r}_n,t)$. Bohmian particle mechanics supplements the wave-function representing the state of a system of particles by ascribing a position $\boldsymbol{r}_i$ to the ith particle that varies continuously in a way that depends on that wave-function. Similarly, Bohmian field mechanics supplements the wave-function representing the state of a quantum field by the assignment of a particular classical field configuration that varies continuously in a way that depends on the wave-function. The wave-function then represents (a probability distribution over) all possible field configurations, while the actual state of the quantum field is represented by one particular classical field configuration.

According to Bohm’s own interpretation of the theory of the quantized electromagnetic field, the state of a free field at each moment is given by a particular classical vector potential $\boldsymbol{A(r,t)}$, whose evolution is specified by a wave-function $\Psi[\boldsymbol{A(r,t)}]$. This potential gives rise to a corresponding classical electromagnetic field F, but it is also responsible for effects even in regions where that field is everywhere zero.

The same reasoning that motivated associating holistic properties with classical electromagnetism also favors taking the holonomies of $\boldsymbol{A}$, instead of $\boldsymbol{A}$ itself, to represent holistic properties on a Bohmian interpretation of the quantized electromagnetic field. A similar Bohmian interpretation may also be offered for the other free bosonic gauge fields of the Standard Model.

But this is only half the story: the empirical success of the theory stems from its application to interactions between these gauge fields and the electron and other fermion fields. A complete Bohmian ontology has to apply to those fermion fields also. But here problems arise. For a classical Bohmian fermion field is represented by functions that assign Grassman numbers rather than ordinary numbers to space-time points. (A non-zero Grassman number η may satisfy the equation $\eta^2 = 0$!) I don’t know how to make sense of such a field, either on a local property or on a global substance conception of fields. Even if one could make sense of a Grassman electron field, its basic ontology would not include electrons. We are a long way here from any kind of basic atomistic ontology!

One idea (of Struyve and Westman(2007)) is to treat fermionic fields as ontologically parasitic on bosonic gauge fields—as representing uninterpreted additional degrees of freedom of those fields. The idea is that fermions, and fermionic fields, don’t contribute to ontology—in a sense electrons and the electron field have no independent existence. But they are not exactly fictions either. Rather, they represent additional “hidden” structures of a fundamentally bosonic world. This would invert the usual ontological priority of matter (made of fermions) over force (mediated by bosons). It would also represent a novel twist on Berkeley’s doctrine of *esse est percipi*, in so far as it portrays the world as constituted by the very bosonic fields (primarily the electromagnetic field) that mediate all our sensory contact with it.

5. A Monist Physical Ontology?

The problem of giving *any* coherent ontological interpretation of quantum field theory may seem so intractable as to tempt a retreat into instrumentalism. An instrumentalist is content to regard quantum field theory as merely a remarkably successful tool for accurately predicting and organizing information about observable results in a wide variety of experimental situations. This attitude was recommended by Davies(1984) in his provocatively titled "Particles do not Exist":

> There are quantum states and there are particle detectors. Quantum field theory enables us to predict probabilistically how a particular detector will respond to that state. That is all. That is all there can ever be in physics, because physics is about the observations and measurements that we can make in the world. We can't talk meaningfully about whether such-and-such a state contains particles except in the context of a specified particle detector measurement. (69)

But one non-instrumentalist option is always available for the ontology of any physical theory—namely the World!

Here's the idea. What is there in a world described by the theories of the Standard Model? Ultimately, there is only one object—the world itself. It has no parts—neither elementary particles, nor space-time points, nor particle-detectors, nor people, nor planets nor galaxies. It neither perdures nor endures: like space-time (if there were such a thing!), it exists atemporally. But it has an enormously rich *structure*—so rich, in fact, that everything we think of as an ordinary or extraordinary object emerges as an aspect of this structure. The quantum field theories of the Standard Model give us ways of modeling details of this structure that are not available to us in any other way. Other scientific theories, as well as everyday beliefs, model other aspects of world-structure. But none of these systems of thought and experience ultimately refer to any objects except the world itself.

A classical field theory like general relativity is capable of modeling the structure of the world as a whole; which is to say that it permits structural ascriptions relating properties every space-time-point-wise. A quantum field theory offers only more limited models, though these can capture more details of world-structure within their limits.

From this point of view, a composition relation itself emerges as higher-order structure. All nontrivial claims of composition are literally false, since the World has no parts. But aspects of world-structure themselves display a structure that warrants us in making compositional claims on whose truth-value we can come to agree—for example, the claim that a proton is composed of two up quarks and one down quark, or the claim that your nose is part of your face.

Turning this idea into an argument for existence monism requires appeal to the fundamental status of the Standard Model within contemporary physics. We do not believe that the interacting quantum field theories of the Standard Model will be physics's last word on the fundamental structure of the world. But the success of those theories, as the present cutting edge of a progressive research tradition in quantum field theory that began with quantum electrodynamics, may be thought to warrant the following claim:

(5) We have reason to believe that a completely successful fundamental theory of physics will be a quantum field theory.

Success would include explanatory power as well as predictive accuracy. Complete success would require that the theory provide a unified account of the world. What is it for a theory to be fundamental? Here is one plausible way to cash out this condition:

(6) A theory of physics is fundamental if and only if its description of the world suffices to account for every other feature of the world.

Of course this leaves open the question as to just what *are* those features, and what it takes to account for them. But it will not be necessary to provide a complete answer to this question to use (6) together with (5) in the following argument for existence monism.

(5) We have reason to believe that a completely successful fundamental theory of physics will be a quantum field theory.
(6) A theory of physics is fundamental if and only if its description of the world suffices to account for every other feature of the world.
(7) A quantum field theory does not describe any proper parts of the world.
Therefore
(8) We have reason to believe that any account of the world that describes its proper parts is either false or else incorporates explanatorily redundant or epiphenomenal entities.
But
(9) There are no explanatorily redundant or epiphenomenal entities.
Hence
(10) We have reason to believe that the world is the only concrete object.

How good is this argument? There are several weak points. (9) may be challenged on various grounds, but since (9) and (3) are identical these challenges apply equally to section 3's argument for existence monism based on a unified *classical* field theory. The inference to (8) implicitly assumes (we have reason to believe that) some fundamental theory of physics *will be* completely successful—an assumption that is at most a regulative ideal for physics. In so far as the justification for (1) also rested on a similar, but (given the present state of physics) much less plausible, version of this same implicit assumption, the present argument represents an improvement. Section 4 provided arguments in support of (7). The important difference between section 3's argument for existence monism and the present argument based on a unified *quantum* field theory concerns premise (6).

I believe that objections to (6) fatally undermine this revised physics-based argument for existence monism. As I have argued elsewhere (2010, forthcoming), the success of quantum theory shows us that a physical theory—even a fundamental theory—may be completely successful in all its applications without offering a representation of reality at all. The quantum field theories of the Standard Model serve as examples of highly successful fundamental theories that do not themselves purport to represent or describe the world: rather, they provide us with mathematical objects (including quantum fields and quantum states) that we can use as reliable guides in making descriptive claims in various circumstances. This does not amount to adopting an instrumentalist interpretation of these theories. Such licensed descriptive claims concern matters that are certainly unobservable through unaided human senses: indeed, many can be checked only by using extremely sophisticated instruments whose design and operation cannot be understood without a great deal of theory, often including some form of quantum theory.

The claim of Standard Model theories to be fundamental rests on their position within contemporary physics, and in particular their predictive and explanatory relations to experiment as well as to other physical theories. A wide variety of descriptive claims licensed (but *not* implied) by these theories have been tested and confirmed in high energy accelerators. The theory of quantum electrodynamics (QED) that results from the unified electroweak theory of the Standard Model by spontaneous symmetry breaking has led to some of the most precise and accurate predictions in all of science. While the explanatory relations of Standard Model theories to the rest of physics are complex and interesting, few would wish to take issue with Weinberg's(1992) claim that in some sense

> ...any questions about the physical and chemical properties of calcium carbonate [common chalk] lead us in much the same way through a chain of whys down to the same point of convergence: to our present quantum-mechanical theory of elementary particles, the standard model. (31)

although his further claim that

> no one doubts that with a large enough computer we could in principle explain all the properties of DNA by solving the equations of quantum mechanics for electrons and the nuclei of a few common elements, whose properties are explained in turn by the standard model. (32)

is likely to raise a few eyebrows among biochemists! The quantum field theories of the Standard Model are fundamental not because they *describe* the world in more detail than any other theories in physics or the rest of science, but because they have the widest (potential) application, because we can use them to predict and explain phenomena that no other theory is capable of predicting and/or explaining, and because they help to unify the rest of physics, if not the rest of science.

Where does the failure of this section's argument from the success of the quantum field theories of the Standard Model leave the doctrine of monism? While the argument fails to support existence monism, the reasons for this failure do nothing to undermine premises (5) and (7). A convinced monist can continue to maintain that the best, and perhaps the only, ontology for a completely successful fundamental theory of physics will be the World, since any such theory would be a quantum field theory and no quantum field theory describes any proper part of the World. But what kind of description of the World could such a theory provide? The motivating idea behind the argument was that the World has an enormously rich *structure*—so rich, in fact, that everything we think of as an ordinary or extraordinary object emerges as an aspect of this structure. But if no quantum field theory implies any descriptive or representational claims, then a quantum field theory cannot *itself* model any details of World-structure, even if using it helps *us* to do so. If the World *does* have an enormously rich structure, then quantum field theory is silent on what that structure is. I think this renders vacuous both the claim that a quantum field theory describes the World, and the associated claim that the World provides the best, or the only, ontology for a quantum field theory. Unlike a (hypothetical) unified *classical* field theory, a unified *quantum* field theory would have not a monist but a nihilist ontology. Rather than supporting an argument for existence monism, the success of contemporary quantum field theories undercuts an essential premise of an argument similar to one that might have been based on a unified theory of the kind sought by Einstein—if only such a classical field theory had proved successful.

6) A Pragmatist Alternative

Horgan and Potrč(2008, this volume) have offered a very different argument for existence monism that is independent of details of contemporary science, including fundamental physics. They argue that ordinary language as well as at least a large part of scientific language is vague, whereas neither objects nor properties in the world can be vague. They conclude that, if evaluated in accordance with a semantics requiring direct word-world correspondence, a vast number of familiar claims made in ordinary and scientific language will turn out to be false. In large part to avoid this skeptical consequence they advocate an alternative semantic analysis intended to vindicate these claims by showing that, under contextually operative semantic standards, they come out true when evaluated on the basis of ontologically Austere Indirect Correspondence (AIC). Such correspondence is austere in so far as the only concrete *object* appealed to is the World (which, with tongue firmly in cheek, they call "the blobject").

So now we have three different arguments for existence monism: Horgan and Potrč's semantic argument; and the arguments of sections 3 and 5 of this paper, both of which were analyzed and seen to be flawed. If arguments appealing to unified field theories of fundamental physics don't establish existence monism, does Horgan and Potrč's apparently independent semantic argument? I will argue that, contrary to appearances, these arguments are *not* independent. The critique of the previous section's argument did nothing to undermine premises (5) and (7): but these premises can now be seen to represent a serious challenge to Horgan and Potrč's AIC-based semantics.

Horgan and Potrč(this volume) argue that truth for many kinds of claims made in real-life contexts is plausibly construed as ontologically austere indirect correspondence, so such truth may be non-ontologically vindicated. Ontologically austere indirect correspondence arises

> when (i) the way the world actually is conspires with contextually operative semantic affirmability-standards in such a way that a given thought/statement is correctly affirmable, and (ii) those semantic standards do not require the right ontology to include items that are eligible candidate-referents for the positing apparatus deployed in the thought/statement.

Now suppose that a completely successful fundamental theory of physics will be a quantum field theory, as (5) says we have reason to believe it will be, but (in accordance with (7)) a quantum field theory does not describe any proper parts of the world. Then nothing in a completely successful theory of physics will describe any proper part of the world. Moreover, as we saw in section 5, this is not because fundamental physics will give us an enormously rich description/representation of *global properties* of the world, but because a completely successful theory of physics will not describe the world at all. If the World *does* have an enormously rich structure, then even a completely successful fundamental physical theory will, then, be silent on what that structure is. But that would render the way the world actually is epistemically inaccessible to us, along with its ability to conspire with contextually operative semantic affirmability-standards.

Now it may well be that certain aspects of world-structure will remain forever beyond the ken of cognitively, practically and spatio-temporally limited humankind (or even some future extension of our epistemic community to include non-human inquirers). But nothing can function as a contextually operative semantic affirmability-standard unless it can influence affirmations. We make claims and evaluate them (fallibly) for truth or falsity. It is a precondition of the possibility of this practice that we have adequate understanding of the content of a claim (including the context in which it is made) and sufficient epistemic access to evidence relevant to its evaluation. If we accept that a completely successful fundamental physics fails to describe the structure of the world then we have no epistemic access to the way the world is at a fundamental level and so no way of stating or holding ourselves to the contextually operative semantic affirmability-standards out of which ontologically austere indirect correspondence supposedly arises.

In response to this objection one might argue that there is no need to resort to a fundamental physical theory to say how the world is and to apply contextually operative semantic affirmability-standards to the evaluation of a claim such as

(A) The politics of Arizona is much discussed in the American news media.

All one has to do is to sketch ways the world might be in broad-brush strokes to establish that the way our world actually is suffices to render it semantically correct to affirm (A) under contextually operative semantic affirmability-standards. But how would this sketching go? Suppose one appealed to a characterization of worlds in terms of their distributions of ordinary physical properties (shapes, sizes, colors, etc.) of macroscopic physical objects (landmasses with geographical boundaries; human bodies, buildings, TV sets, broadcast antennae, electrical and cable connections, newspapers, etc.). Such a characterization would be vague, and so would itself have to be evaluated under AIC standards, requiring a more fine-grained description of worlds in microscopic physical terms (atomic constitution of deserts, TV sets and human bodies; wavelengths of broadcast radiation, etc). This is still vague, necessitating a characterization in terms of "elementary particles" such as electrons, quarks and photons. But now we have reached the level of fundamental physics, and section 4 queried the ontological credentials of such "objects" within a quantum field theory. The program of non-ontological vindication supposedly "bottoms out" in a direct correspondence account of truth connecting statements in some hypothetical non-vague scientific language of fundamental physics to enormously complex structural properties of a single object, the blobject. With no such direct correspondence foundation, the whole structure collapses. Acceptance of (5) and (7) removes the foundation.

And yet we *do* succeed in affirming claims like (A) and evaluating them for truth and falsity, despite their undoubted vagueness. Moreover, scientists confidently affirm their beliefs about elementary particles, even if quantum field theory itself describes no such objects. Here are three examples.

> "Here, right now, in a little cylindrical domain...in the center of our Penning trap resides positron (or anti-electron) Priscilla, who has been giving spontaneous and command performances of her quantum jump ballets for the last three months."

Wick(1995,137) quotes this from the press release reporting the results of experiments conducted in Hans Dehmelt's laboratory in1984 with a Penning trap—a device whose name indicates its alleged function of confining charged particles by means of electromagnetic fields. Dehmelt was awarded a Nobel prize in 1989 for his research on Priscilla and other isolated charged particles. The most expensive and elaborate experimental device ever built (the Large Hadron Collider—a proton accelerator) is currently in operation in Geneva with the declared aim of putting the finishing touches to the Standard Model by producing and detecting the elusive Higgs boson. Recently a group at CERN claimed success in a different experiment. By producing and trapping large numbers of positrons and antiprotons (the antiparticles of protons) they were able to combine some of them into atoms of antimatter—specifically, anti-hydrogen—which they were able to store for a short period before they annihilated with matter in their container.

Why are scientists correct to affirm that Priscilla resided in the center of Dehmelt's Penning trap for three months in 1984, and that 38 atoms of anti-hydrogen formed from positrons and antiprotons created at CERN were recently trapped for about 1/6 of a second? What would make them correct to affirm that the LHC has discovered the Higgs boson? Such affirmations may be *justified* by the evidence adduced in their support. But of course such evidence does not entail the *truth* of what is affirmed. Claims based on strong evidence may be retracted subsequently on the basis of additional evidence, in science as in daily life. For it to be *correct* to affirm that the Higgs boson has been discovered at the LHC two conditions must be satisfied:

(a) The situation to which the claim pertains must be one in which the relevant quantum field theory *licenses* the claim that a Higgs particle is present, and

(b) The experimental evidence provided by analyzing the data produced by the detectors must *warrant* that claim.

Condition (b) is a matter of evidence, but condition (a) is not. As I(forthcoming) have argued elsewhere, no quantum theory itself implies any descriptive claim concerning a system such as a particle or field. In particular, a quantum field theory never implies the *existence* of any particle or field: in that sense, the ontology of a quantum field theory contains neither fields nor particles nor any other physical system. That is why I called it a nihilist ontology in section 5.

But a quantum theory may be applied in a situation in which it licenses a user of the theory to make various descriptive claims about one or more physical systems. Such a license may be more or less restricted in scope: the wider the license, the more material inferences from that claim are permitted. Since the *content* of such a claim is a function of the web of material inferences in which it is embedded, (a) is a semantic rather than an epistemic condition. So correctness of an affirmation of existence based on a quantum field theory has a semantic component. But this is neither grounded in nor grounds any correspondence notion of *truth*, indirect, direct or AIC.

So what would it take for statement (H) to be true?

(H) The Higgs boson is discovered at CERN during the 21st century.

As Tarski insisted,

(H) is true if and only if the Higgs boson is discovered at CERN during the 21st century.

But surely if (H) is true then at least one Higgs boson exists at some time during the 21st century? Yes, indeed. If conditions (a) and (b) are satisfied, then the claim

(E) A Higgs boson exists at some time during the 21st century.

is both licensed and warranted, because (H) is. If (H) is true, so is (E). But what would then *make* (H) and (E) true is not a relation of direct or indirect correspondence between these claims and the world somehow set up by physicists and other language-users that involves a highly selective referential mechanism (causal or otherwise) between the term 'Higgs boson' and physical objects or properties (Higgs bosons, *is a Higgs boson*, the World, *manifests Higgs-boson-ness-CERN-21st century-wise*). In answer to a demand for a truth-maker for statements such as (H) and (E), the best thing one can do is to simply (re)assert that very claim, backed up (if this is found unsatisfying) by as complete as possible an account of the evidential grounds on which it rests. There is nothing more to be said in response to a demand for truth-makers for (H) and (E) than one would find in the published paper reporting and justifying the claim, amplified by the collective knowledge and wisdom of its authors as well as the whole community of physicists involved, including their abilities as users of the various natural (and technical) languages in which they communicate.

More generally, there is not much more to be said about truth, and nothing more should be said in the attempt to cash out the metaphor of truth as correspondence—to Reality, to the Facts or to anything else. It is not necessary to vindicate true claims (including (A)) by showing how they may be seen to correspond to the world. The important questions are how a claim gets its content, and how it is evaluated on the basis of the evidence. The concept of truth is best avoided while addressing these questions. Any residual questions about truth concern the role that concept plays in the social practice of communicative discourse, among scientists just as among the rest of us.

7) Conclusion

Existence monism is the thesis that there is exactly one concrete object—the World, or the blobject. One kind of argument for this thesis appeals to considerations drawn from science, and specifically to aspects of fundamental physics. In Einstein's view, a fundamental theory of physics would permit a complete description of the world at the deepest level—a description sufficient (in principle) to determine exactly how the world is. His own attempts to create a fundamental unified field theory did not succeed. Had they succeeded, a classical unified field theory could have provided the basis for a serious argument for existence monism—an argument that would certainly have appealed to a Spinozistic thinker like Einstein himself.

But fundamental physics took a different path, which has so far led to the interacting quantum field theories of the Standard Model. Though highly successful, these theories do not themselves constitute a fully unified fundamental quantum field theory. But their success does provide some reason to believe that a completely successful fundamental physics would take the form of a quantum field theory. However, convincing objections have been raised against interpretations of a quantum field theory that portrays this as describing elementary particles, fields, or any other physical system, including the world as a whole. This does not show that no quantum field theory can be fundamental, if what is required of a fundamental theory of physics is that we can use it successfully to predict and completely to account for all physical phenomena in a unified way. But it does mean that such a unified *quantum* field theory would provide no basis for an analogous argument for existence monism.

A different kind of argument for that thesis appeals to the semantics of our language, ordinary as well as scientific. This argument (due to Horgan and Potrč) employs an account of truth as AIC correspondence. For AIC correspondence to hold between a statement *S* and the world, there must be some relation of direct correspondence between statements or thought-contents and the world as a whole that makes *S* true. The ability to apply contextually operative semantic standards so as to evaluate the truth of a statement *S* in terms of AIC correspondence ultimately rests on the possibility of epistemic access to this relation of direct correspondence. But we have reason to believe that even if we had a completely successful fundamental physical theory we would still not have such access. While this does not settle the question as to whether the world *has* some determinate structure at a fundamental level (or the prior question as to what this could mean), it does show that we have reason to believe that our ability correctly to make and justify claims about the world does not depend on the assumption that the world has some determinate structure at a fundamental level.

Physicists use quantum theories, including the quantum field theories of the Standard Model, to guide them in determining both the correct affirmability and the content of claims about particles, fields and other physical items. They have developed the instrumental, mathematical and conceptual resources to permit sensitive evaluation of the evidence for or against such claims. They are often in a position authoritatively to judge some such claims true and others false on the basis of such evidence, though any particular judgment remains fallible. The judgment that an elementary particle (such as an electron or the Higgs boson) exists with certain properties may authoritatively be judged as true even though no completely successful fundamental physical theory ascribes these properties to this particle or includes the particle in its ontology.

Truth does not rest on direct correspondence even at the level of fundamental physics. Tarski *T*-sentences express an insubstantial kind of word-world correspondence at any level of science or daily life. Armed with such insubstantial correspondence, one can cheerfully adopt a pluralist ontology of electrons, photons, classical electromagnetic as well as gravitational fields, acids, mitochondria, and slime molds within science; states, media and politics in the social sphere; and the blobject for philosophers who want it. Each such ontology works well within its own limits, and each underwrites truth claims. But as James and Carnap told us, there is no single right ontology.

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