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HACKING AWAY AT THE IDENTITY OF INDISCERNIBLES: POSSIBLE WORLDS AND EINSTEIN'S PRINCIPLE OF EQUIVALENCE*

Is G. W. Leibniz's principle of the identity of indiscernibles (henceforth PII) a necessary truth? Faced with Max Black's[1] famous two-globe counterexample, many supporters of PII have staged a strategic retreat to the claim that it is, in fact, only contingent.[2] Yet even this position has been challenged by recent considerations of the symmetries to be found in quantum mechanics,[3] leaving, as a last possible option, the thought that PII may still be a useful methodological principle.[4] It is in this role that it appears in discussions of the foundations of space-time physics, particularly within a conventionalist context where it is argued that space-time descriptions, or models, which are indistinguishable with respect to some aspect, such as underlying causal structure, should be regarded as identical in the sense of describing the same physical situation. The choice between descriptions is then taken to be purely conventional.

* This paper began life as a commentary on G. Landini and T. Foster's "Einstein's Principle of Equivalence and Hacking's Defense of the Identity of Indiscernibles," presented at the Pacific Division Meeting of the American Philosophical Association in 1990 (subsequently published in expanded but essentially unchanged form as "The Persistence of Counterexample: Re-examining the Debate over Leibniz's Law," *Noûs*, XV (1991): 43–61). An earlier version was presented to the Eastern Division Meeting of the APA in December 1992. I am grateful to Richard Arthur for his illuminating comments and to my former colleagues in philosophy at Southeast Missouri State University for their support.

[1] "The Identity of Indiscernibles," *Mind*, LXI (1954): 153–64.

[2] See, for example, A. Casullo, "Particulars, Substrata, and the Identity of Indiscernibles," *Philosophy of Science*, XLIX (1982): 591–603.

[3] M. Redhead and my "Quantum Physics and the Identity of Indiscernibles," *British Journal for the Philosophy of Science*, XXXIX (1989): 233–46.

[4] R.C. Hoy, "Inquiry, Intrinsic Properties, and the Identity of Indiscernibles," *Synthese*, LXI (1984): 275–97.

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Ian Hacking[5] has used such considerations to press the claim that PII should be construed as being true *about* possible worlds, rather than *in* them, and that the well-known counterexamples put forward by Immanuel Kant and, later, Black actually have no bearing on its truth. It is this claim in particular which I wish to examine here and I hope to show that it is not quite so well grounded as Hacking seems to think.

I. HACKING'S ARGUMENT

Hacking asserts that considerations regarding possible worlds are never sufficient to pin down the truth of PII. His argument supporting this assertion rests upon the well-known underdetermination of description to be found in the foundations of space-time physics. The simplest example he gives is that of Newton's renowned thought experiment with a rotating bucket: Newton thought he could refute the relational view of space by asking us to imagine a world with nothing in it but a spinning bucket of water. Although the "spin" of the bucket would not be observable, we could note the difference between the states of spin and rest, without reference to any other object, by observing the rise of the water up the sides of the bucket. As is well known, Ernst Mach argued that this "refutation" is inconclusive since it depends on the assumption that the laws of mechanics of *this* world also apply in Newton's possible one. A different set of laws could explain the change in the meniscus of the water, without recourse to the postulation of a notion of "absolute rest."

The point is then taken to be a perfectly general one and, indeed, forms the backbone of the conventionalist approach to space-time: "There can be no determination of spatial relations without a study of the laws of nature attributed to objects in space. When such laws are prescribed, most of space falls into place" (*ibid.*, p. 250). Following the standard conventionalist line, there exists a form of underdetermination between different possible space-time descriptions. Thus, for example, the phenomena observed in a world whose spatiotemporal background is non-Euclidean are preserved under translation to a world with Euclidean space-time and a different set of physical laws. The latter may be more complex than those of the non-Euclidean world but any choice based on considerations of simplicity is, it is maintained, purely pragmatic.

Hence, Hacking notes: "In arguing that in a certain possible world there exist two distinct but indistinguishable objects, bland assertion is not enough. There must be argument" (*ibid.*, p. 250). The stan-

[5] "The Identity of Indiscernibles," this JOURNAL, LXXII, 9 (May 8, 1975): 249–56.

dard counterexamples, involving possible worlds populated by two indistinguishable objects, proceed by abstraction from our world (Hacking actually uses Kant's counterexample involving two drops of water) but, "[t]he question remains whether the result of this abstraction is correctly described as having two indiscernibles in it. Simply to say so is to beg the question....No matter how vivid your imagination, it remains a question how correctly to describe the content of your imagination" (*ibid.*).

This distinction between imaginability and possibility can be traced back to Leibniz himself, of course. One of the more amusing aspects of *The Leibniz-Clarke Correspondence*[6] is Samuel Clarke's utter bewilderment concerning Leibniz's claim that although we can imagine two indiscernibles, it is not possible that there can be two such things. As far as Clarke is concerned, Leibniz is simply contradicting himself. For Leibniz, however, possibility and impossibility are to be understood in terms of accordance or discordance with God's will; although we fancy that there could be two indiscernible things, this, being contrary to God's will, is not a genuine possibility.[7] PII (and the associated principle of sufficient reason) then, are metaprinciples of possibility and Hacking's "correct description" above corresponds to God's description.

Returning to Hacking's argument, since any such description will involve the attribution of spatiotemporal relations, it will be open to the aforementioned possibility of underdetermination. To put it bluntly, any possible world put forward as a counterexample to PII can be redescribed so as to preserve PII. Thus, Hacking concludes (in line with Leibniz, as one would expect), PII "is not true *in* each possible world. It is true *about* all possible worlds. It is a metaprinciple about possible descriptions. This is part of the force of saying that it is a metaphysical principle" (*op. cit.*, p. 255). What does this force amount to? Hacking answers: "Leibniz *could not* describe a world in which a law of logic was false and *would not* describe any world in such a way that it contravenes [PII]. Whatever God might create, we are clever enough to describe it in such a way that the identity of indiscernibles is preserved. This is a fact not about God but about description, space, time, and the laws that we ascribe to nature" (*op. cit.*, pp. 255–56).

[6] H.G. Alexander, ed. (Manchester, UK: University Press, 1956), pp. 61–63 and p. 100.

[7] As Richard Arthur put it in his comments on the APA version of this paper, Leibniz uses the principle "as a criterion for distinguishing possibly real existents from what are only icons, incomplete notions abstracted from things."

I have given this argument in some detail in order to try to make it quite clear what Hacking is claiming. In particular, it must be emphasized that he is concerned to articulate the constraints imposed on possible descriptions. To appeal merely to imagination or abstraction in admitting such descriptions is to lay oneself open to the charge of question begging.

II. INDISCERNIBILITY AND POSSIBILITY

Perhaps the most obvious response to this argument is to claim that Hacking has simply confused logical with physical possibility. The premises on which his argument rests involve the latter, whereas the standard counterexamples are concerned with the former. Thus, A. Denkel,[8] for example, argues that: "the existence of a consistent description of a counterexample involving two distinct objects which are indiscernible should be sufficient for refuting the principle. That there is an 'equivalent' description which assumes a non-Euclidean space is no hindrance here. For the point is that even in such a space there *could* be two distinct indiscernibles" (*ibid.*, pp. 214–15, fn. 3). The point is, according to Hacking, what there could or could not be is not something that can be "blandly" asserted. The lesson to be drawn from the history of physics is that the determination of spatial relations is not something that can be established independently of a consideration of the laws of nature; there is an interdependence here which must be taken account of if we are not to beg the question against PII.

Underlying this discussion are a number of important assumptions concerning the nature of possible worlds and the role they play as "truth makers" for propositions such as that expressed in PII. Thus, Denkel continues:

> It needs to be remembered that in devising such [Blackian] counterexamples we are not describing something which has an existence independent of the description itself. We are not taking photographs or observing something which is out there. We are constructing the world as we are describing it. So we are not forced to think first of indiscernibility and then observe whether or not indiscernibles can be distinct in this or that conception of space. We can begin our argument (as Black does) by positing two distinct objects whatever the nature of space they are in, and try to give a consistent description of them as indiscernibles (*ibid.*).

But, Hacking notes, it is precisely the correct description of the content of our imagination which is in question here. On his view, "cor-

[8] "*Principia Individuationis*," *Philosophical Quarterly*, XLI (1991): 212–20.

rectness" is not something that can simply be conferred willy-nilly; rather, it is something that must be argued for and, in particular, argued for on the basis of our current understanding of the relationship between space and the objects *in* it.

According to the "standard" approach to this issue, as represented by Denkel, the logical possibility of a "Blackian" situation is enough, whatever the actual relationships are between space-time geometry, natural laws, and physical objects. In the absence of a clear and noncircular distinction between logical and physical possibility, however, such a response obviously begs the question in precisely the sense noted above.

In a recent attempt to specify the terms in which such a distinction might be laid out and thus avoid any charge of question begging, G. Landini and T. Foster (*op. cit.*) have noted that different forms of PII arise depending on the theory of universals adopted. Thus, they distinguish between *logical realism, attribute realism,* and *natural realism.* From the point of view of logical realism, universals subsist in a way that is independent of the physical world and every well-formed predicate expression stands for a universal. Since logical truth is taken to be truth in virtue of universals, PII can be regarded as logically true within this framework. Placing restrictions on which well-formed formulas stand for universals then gives rise to a form of attribute realism. In particular, if proper names and free variables are excluded from expressions that stand for universals, a restricted notion of indiscernibility results and PII may no longer be a logical truth. Since Black imposes just such a restriction in his argument, he is counted as an attribute realist and, according to Landini and Foster, much of the discussion of the status of PII is carried on without acknowledging this particular philosophical framework. With logical truth understood in the attribute realist's sense, Black's counterexample counts against PII.

Finally, natural realism is an altogether different kettle of fish. The universals of this view do not transcend the causal structure of the world and are physical properties and relations that are "causally realizable," in the sense that they are realized in some world that is possible relative to the laws of nature. With universals understood in this manner, the form of PII then obtained is not "conceptually" necessary, in the sense of being true in *all* possible worlds (including those which are not physically possible). It may, however, be "physically" necessary, in the sense of being true in all worlds possible relative to the laws of nature.

The upshot is that "it is a confusion to present physically possible worlds in an argument against the conceptual (or logical) necessity of the PII" (*op. cit.*, p. 55). According to Landini and Foster, Hacking stands condemned for making just such a confusion since his argument is based on empirical truths concerning physics and is thus applicable only to the form of PII obtained within the ambit of natural realism. Hacking's argument, they claim, rests on empirical principles concerning the relationships between the physical forces and geometry of our universe and the objects that populate it. Such principles are simply irrelevant to the question of the logical truth of PII understood from either the logical or attribute realists' viewpoints. Black, in particular, is not restricted to physically possible worlds and his counterexample to the logical necessity of PII, taken in the context of attribute realism, remains unaffected by Hacking's argument. In particular, they distinguish between those views which hold that universals subsist in a way that is independent of the physical world and the view that they are physical properties and relations that are "causally realizable," in the sense of being realized in some world that is possible relative to the laws of nature (*op. cit.* p. 52). This then grounds the distinction between *conceptual*, or *logical*, necessity, in the sense of being true in *all* possible worlds (including those which are not physically possible) and *physical* necessity, in the sense of being true in all worlds possible relative to the laws of nature.

III. HACKING ON LOGIC

It is curious that the above authors fail to consider Hacking's own views on the nature of logic[9] and, in particular, the difference between *real* and *logical* predicates,[10] on the basis of which a suitable reply to their arguments might be constructed. Hacking essentially combines Ludwig Wittgenstein's "by-product" theory of logic, according to which certain classes of logical truth are simply by-products of facts about the use of logical constants, with Gentzen's introduction of the sequent calculus, by means of which a logical constant can be distinguished as anything defined by means of a "Gentzen-like" rule of inference.[11] A logical predicate is then a predicate that can be introduced by a Gentzen-like rule, whereas a real one cannot be so introduced. Thus, logical predicates are to be understood as "planted on top of" the real, using rules for the introduc-

[9] "What Is Logic?" this JOURNAL, LXXVI, 6 (June 1979): 285–319.

[10] "On the Reality of Existence and Identity," *Canadian Journal of Philosophy*, VIII (1978): 613–32.

[11] "What Is Logic?"

tion of a new notation,[12] so that, if two individuals share all their real predicates, they will also share all the logical ones that can be introduced (*ibid.*, p. 620).[13]

Possible worlds are then stipulated on the basis of the actual world but, Hacking admonishes us, we must not assume that, if two descriptions are not logically equivalent, then two distinct possible worlds are defined. Using Kant's raindrop example, he notes that by a series of acts of abstraction we can stipulate two "descriptions," each inhabited by an individual utterly indistinguishable from the other except insofar as they have different names.[14] But in doing so, he argues, we have not stipulated two distinct possible worlds, since "there is no sense in postulating two distinct possible worlds which have no points of distinction except in the sheer names of their inhabitants" (*ibid.*, p. 626). Hence, "cold naked stipulation" (*ibid.*) cannot be regarded as sufficient for the elaboration of possible worlds.

An analogous example may help clarify the overall strategy here: consider the question whether there could be nothing at all. Many philosophers have answered "yes," since we can certainly *imagine* such a possibility. In the absence of a fully worked out theory of possibility, however, it may be questioned whether this is a good reason for holding that there could have been nothing at all. Indeed, D. M. Armstrong[15] has recently argued that "the idea that there could have been nothing at all is really a *superficial* idea. It is attractive at a relatively shallow level of reflection. But when we think more deeply about the nature of possibility, then, it seems, it has to be given up" (*ibid.*, p. 25). In similar fashion, Hacking could reply to Foster and Landini's criticisms that the distinction between logical and physical necessity is intuitively attractive, but when we think more deeply about the nature of logic, then we may discover that it has to be given up (at least in the form in which they present it).

IV. THE "EMPIRICAL TRUTH" OF CONVENTIONALISM

It is not the intention of the present paper, however, to shore up Hacking's defense of PII in this manner. Rather, I think that he can best be attacked from an entirely different direction. Let me begin with the claim that his argument is based on an "empirical truth."

[12] "On the Reality of Existence and Identity," p. 617.

[13] The principle of the identity of indiscernibles can then be derived from Gentzen-like rules which define the relation of identity and establish it as a logical constant according to Hacking's criterion. It is worth noting that Hacking states that he is not interested in defending the truth of PII here, although he does cite his "space-time" defense of it.

[14] "On the Reality of Existence and Identity," pp. 625–26.

[15] *A Combinatorial Theory of Possibility* (New York: Cambridge, 1989).

Landini and Foster defend this claim by filling in the support for the argument through a rather superficial account of the standard conventionalist approach to space-time theory. Thus, they begin by acknowledging Hans Reichenbach's[16] claim that Newton's thought experiment with the bucket was mistaken since inertial and gravitational forces are covariant, in the sense that they vary depending upon the frame of reference adopted. They then go on to give Mach's objection to Newton's argument—that the rising of the water in the bucket could be explained by referring either to absolute space or to the gravitational effects of the fixed stars and that there is no way of verifying which description is the correct one—and claim that this was then incorporated into Einstein's theory of general relativity in the form of his principle of equivalence. This is empirically testable, "because the precise relationship of inertial and gravitational forces expressed in the law of the equality of inertial and gravitational mass is held to be due to the non-Euclidean metric of space—a metric whose deviation from the Euclidean is measurable" (*op. cit.*, p. 57). Finally, they conclude with the well-known conventionalist line that there is an equivalence between the Euclidean and non-Euclidean descriptions in the sense that we could continue to describe the geometry of space in terms of the former, provided we make suitable changes in the laws of physics. The choice between the two descriptions is merely pragmatic. Likewise: "In Hacking's view, adherence to the Identity of Indiscernibles reflects a pragmatic choice among equivalent descriptions. His position is analogous to Poincare's conventionalist views concerning geometry. We can always redescribe any physically possible world in which the Identity of Indiscernibles fails in such a way that it is preserved" (*op. cit.*, p. 57). Hence the conclusion that Hacking's argument is irrelevant so far as the standard counterexamples are concerned, since it rests on an essentially empirical premise.

The exact nature and status of this premise are opaque, however, to say the least. If it is taken to be some form of Mach's principle, then it should be pointed out that it is now generally agreed that general relativity fails to incorporate this in any significant sense.[17] If it is the principle of equivalence, as Hacking[18] suggests in another pa-

[16] *The Philosophy of Space and Time* (New York: Dover, 1958), p. 212.

[17] To give two examples of violations of this principle within the theory: general relativity retains the notion of an invariant rest-mass, which is an inertial property of matter, and it is possible to define an absolute four-dimensional rotation vector on the space-time manifold.

[18] "Why Motion Is Only a Well-founded Phenomenon," in K. Okruhlik and J.A. Brown, eds., *The Natural Philosophy of Leibniz* (Boston: Reidel, 1975), pp. 131–50.

per, then it can be replied that, as is well known, the theoretical status of this principle is the subject of some debate; indeed, it has been described as the midwife at the birth of general relativity who must now be buried, albeit with all due honor.[19] In particular, the familiar claim must be resisted that what this principle implies is that one can always transform away an arbitrary gravitational field, since "true" gravitational fields cannot be so transformed away, their presence being determined by the curvature of the metric, which is invariant.[20]

Perhaps it is some principle of covariance which is being called upon, as Landini and Foster also suggest. But such principles have been described as formal, rather than factual, being mathematical metatheorems.[21] Hacking[22] himself also explicitly appeals to the well-known underdetermination thesis but, again, one would be hard put to describe this as *empirical.* Furthermore, if such an appeal is to be more than a form of "cold naked stipulation," it must be based on some underlying (and acceptable) physical principle. As we have just seen, however, the only principles that seem capable of doing the job are no longer regarded as being embodied in currently accepted physical theory. As for conventionalism in general, the arguments against this doctrine are well known. In particular, the claim can be pressed that it arises from the failure to distinguish conceptual structures from physical ones as the referents of physical theories:[23] that differentiable manifolds are metrically amorphous, and allow of different geometries, is a fact about mathematics, rather than physics.

Thus, the assertion that Hacking's argument is based on some well-established "empirical truth" fails to receive the support it requires. Indeed, by buying into the whole conventionalist package, Landini and Foster let Hacking get away with too much. After berat-

[19] J.L. Synge, *Relativity: The General Theory* (Amsterdam: North-Holland, 1960), pp. ix–x.

[20] Thus, what the principle of equivalence really asserts is that the properties of space, as manifested through inertial effects, are actually the properties of a field structure in space, which same structure also governs gravitational effects. According to J. Norton, it was unfortunate that Einstein's contemporaries seized upon one of his intermediate results, that in certain cases the existence of gravitational fields is dependent on the frame of reference—"What Was Einstein's Principle of Equivalence?" *Studies in History and Philosophy of Science,* XVI (1985): 203–46. Generalizing this result from the case of Minkowski space-time gives rise to the "infinitesimal principle of equivalence" which Einstein never endorsed and, in fact, attacked in his early correspondence.

[21] M. Bunge, "Laws of Physical Laws," *American Journal of Physics,* XXIX (1961): 518–29.

[22] "Why Motion Is Only a Well-founded Phenomenon," p. 147.

[23] Such a failure might conceivably be regarded, at least in Hacking's case, as having been encouraged by his view of logic.

ing him for failing to distinguish conceptual from physical possibility, they agree that, in the context of the latter, he is correct in maintaining that PII can always be preserved. I shall now argue that this is not so and that further considerations of indistinguishability as it is understood in space-time physics suggest that the argument is not well founded, not even in the realm of the physically possible.

V. SPACE, TIME, AND INDISCERNIBILITY

We recall Hacking's point that PII should not be taken as applicable *within* worlds, possible or actual, but *to* them. It should be regarded as stating that indistinguishable worlds, or descriptions, must be regarded as identical and it is in this respect that the ties with conventionalism are most obvious. In general, any possible world can be described, spatiotemporally, in terms of an n-tuple of elements, including a manifold, a metric, a set of objects (fields, and so on), and the extension of the set of predicates of these objects. The conventionalist and supporter of PII will typically appeal to the invariance across worlds of only certain of these elements in claiming that the worlds are indistinguishable and therefore identical. Other elements, which may differ between the descriptions, are regarded as being devoid of significance. One option, then, for the opponent of PII is to argue against the exclusion of these other elements in the description which, it is claimed, establish the possible worlds as distinguishable.

This is what lies behind R.M. Adams's[24] objection to Hacking's argument, for example. Hacking effectively invokes a form of indistinguishability according to which differences in the objects populating the two worlds, such as iron globes or water drops, do not count since they are compensated for, at the level of empirical observation, by differences in the topology. Adams, however, argues that the two worlds do not offer equivalent descriptions precisely because the sets of objects are not the same. The two worlds differ in the number of "thisnesses" or haecceities which they contain. Of course, a good Leibnizian will want to deny the existence of such "thisnesses" (presumably Hacking would wish to be included here, given his anti-essentialist stance in general) but the alternative "bundle theory" of individuality depends on PII as applied to individuals and there are good reasons for rejecting the latter.[25]

Hoy, on the other hand, has argued that the two worlds should not be identified because they have different topologies (*op. cit.*). In

[24] Primitive Thisness and Primitive Identity," this JOURNAL, LXXIV, 1 (January 1979): 5–26.

[25] See fn. 3 above.

this case, our true-blue Leibnizian friend will want to deny the ontological importance of such differences, claiming that space-time structure can be reduced to nothing but relations among the objects in a world. But she then runs into Adams's objection above and must still accept that the worlds cannot be identified, unless she is also a bundle theorist, which position will lead her into a well-known circularity (space-time is then regarded as being reducible to relations among objects regarded as bundles of properties and relations and individuated by their spatiotemporal relations[26]).

Nevertheless, a supporter of PII might insist that these differences simply do not count. Ultimately, it is causal structure that is important, empirically speaking, and if this is the same in the two worlds then they must be taken to be identical. Here again the Leibnizian runs into trouble, however. Thus, let us return to the (in)famous bucket of water example which occupies such a central role in Hacking's argument. Two possible worlds are imagined, in one of which we have the standard space-time metric and the bucket is regarded as rotating, with the concavity of the water's surface explained by centrifugal effects. In the other, a nonstandard metric is assumed and the bucket is then regarded as nonrotating, with peculiar forces introduced to explain the concavity. According to the conventionalist, these two worlds are identical in the sense that they scribe the same situation and it is a matter of convention which one we choose. As Reichenbach emphasized (*op. cit.*), the basis for this claim is that the two worlds are indistinguishable as regards their causal structure, regarded as "factual" in character.

If two such worlds agree at the level of local causal structure, however, then they must also agree in their respective determinations of whether bodies are rotating, since local causal structure determines conformal structure and the condition of nonrotation is conformally invariant.[27] In other words, if there is agreement at the "factual" level, there must also be agreement about whether the bucket is "really" rotating and, in general, attributions of "absolute" rotation make perfectly good sense according to general relativity. Thus, we simply do not have two different, yet indistinguishable, descriptions to choose from. This approach differs from that adopted by Adams and Hoy in that one does not argue that the two worlds are actually distinguishable, but rather that one cannot generate "two" such

[26] C.A. Hooker, "Remarks on the Principle of the Identity of Indiscernibles," *Southwest Journal of Philosophy*, VI (1975): 129–53.

[27] D. Malament, "A Modest Remark about Reichenbach, Rotation, and General Relativity," *Philosophy of Science*, LXI (1985): 615–20.

worlds to begin with. Hacking's argument is completely undermined since, returning to the bucket experiment, it is not the case that, with causal structure held invariant, we can choose whether to regard the bucket as "really" rotating or not. There is simply no underdetermination of description in this situation.

VI. PHYSICS AND METAPHYSICS

If PII is not to be vacuous, methodologically speaking, then the terms in which two descriptions are to be regarded as indiscernible must be spelled out. The standard conventionalist way of doing this is to invoke causal structure. But then, as we have just seen, there are no longer two descriptions to consider. Hacking makes the mistake of confusing a particular physical theory—namely, general relativity—with that theory as understood, and interpreted, within a particular philosophical program—namely, conventionalism.[28] It is simply not the case that his view of PII as a metaphysical metaprinciple rests on an "empirical truth" of general relativity; rather, it is drawn from a particular understanding of the latter, and one that is certainly open to question. (The mistake is unfortunately perpetuated by Hacking's critics.)

Thus, it is erroneous to suggest that physics may be used to uniquely support a particular piece of metaphysics. This is an instance of a perfectly general point: a physical theory may support more than one metaphysical package.[29] There is, in effect, a kind of underdetermination of metaphysics by physics and any apparent inclination of the latter to support a particular form of the former is a result of some prior tacit assumptions that will themselves be metaphysical in character. Putting it bluntly, you get only as much metaphysics out of a physical theory as you put in and pulling metaphysical rabbits out of physical hats does indeed involve a certain amount of philosophical sleight of hand.[30]

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[28] In this context, Michael Friedman has argued that the status of PII as a methodological principle is dependent upon a further principle concerning theory unification—*Foundations of Space-Time Theories* (Princeton: University Press, 1983), pp. 334–39.

[29] Witness the debate between the defenders of the conventionalist and "space-time" approaches to relativity theory.

[30] It is interesting to note that Leibniz himself appealed to metaphysical principles in order to resolve underdetermination at the level of scientific theories—W. Seager, "Leibniz and Scientific Realism," in Okruhlik and Brown, pp. 315–30.