

---

Quantum Physics, the Identity of Indiscernibles, and Some Unanswered Questions

Author(s): Paul Teller

Source: *Philosophy of Science*, Jun., 1983, Vol. 50, No. 2 (Jun., 1983), pp. 309-319

Published by: The University of Chicago Press on behalf of the Philosophy of Science Association

Stable URL: <https://www.jstor.org/stable/188017>

#### REFERENCES

Linked references are available on JSTOR for this article:

[https://www.jstor.org/stable/188017?seq=1&cid=pdf-reference#references\\_tab\\_contents](https://www.jstor.org/stable/188017?seq=1&cid=pdf-reference#references_tab_contents)

You may need to log in to JSTOR to access the linked references.

---

JSTOR is a not-for-profit service that helps scholars, researchers, and students discover, use, and build upon a wide range of content in a trusted digital archive. We use information technology and tools to increase productivity and facilitate new forms of scholarship. For more information about JSTOR, please contact [support@jstor.org](mailto:support@jstor.org).

Your use of the JSTOR archive indicates your acceptance of the Terms & Conditions of Use, available at <https://about.jstor.org/terms>



The University of Chicago Press and Philosophy of Science Association are collaborating with JSTOR to digitize, preserve and extend access to *Philosophy of Science*

JSTOR

**DISCUSSION:**  
**QUANTUM PHYSICS, THE IDENTITY OF INDISCERNIBLES,  
AND SOME UNANSWERED QUESTIONS\***

PAUL TELLER

*Department of Philosophy  
University of Illinois at Chicago Circle*

A series of papers in *Philosophy of Science* have debated whether quantum physics shows there to be something wrong with Leibniz's principle that things which agree in all their properties and relations are identical. To begin with, I think we can learn something by considering an example somewhat different from the one on which the previous authors have focused. You and I hold the two ends of a rope and at the same moment each of us gives his respective end a little shake. This produces two waves which travel away from each of us, merge in the middle in a single bump, pass through each other, and continue on down the rope:

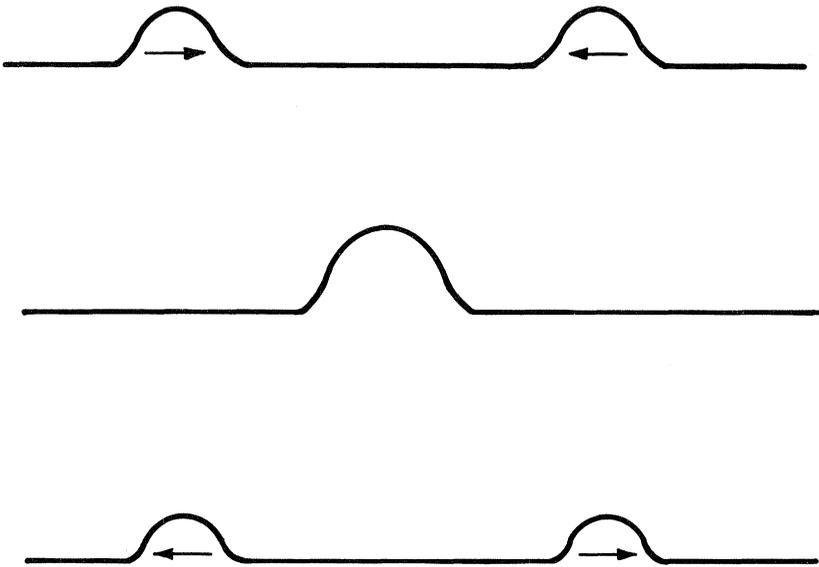


Figure 1.

\*Received May 1982.

*Philosophy of Science*, 50 (1983) pp. 309–319.  
Copyright © 1983 by the Philosophy of Science Association.

Now, one might think of arguing as follows: When the two waves merge in the middle, there is no property which one of them has at that time which the other lacks. The two are utterly indistinguishable. So two things, my wave and your wave, can share all their properties, and Leibniz's principle is shown to be false.

A defender of Leibniz's principle might object, arguing that even when the waves are merged, mine has the historical property of having come from my end, and yours from yours, and that this individuates the waves. But the opponent will reply that there is nothing about the wave coming towards me after merging in the middle which makes it the same as the one that started out at your hand. To see this, consider that we could have produced the bump in the middle, or one exactly like it, in other ways. For example, if we had jerked the middle of the straight rope in just the right way two waves would have emerged, exactly as in the original example, one traveling toward me and the other towards you. All we can say about the original example is that the two initial waves fed into a bump in the middle, which could, in principle, have been caused in other ways, that two waves came out of this middle bump, and these traveled out towards the two ends of the rope. Since we cannot distinguish the parts of the bump in the middle, there is nothing distinctive about the parts which makes one of them the one produced by my wave and the other the one produced by yours.

The debate continues. The defender objects that the last argument confuses metaphysics with epistemology. We may not be able to tell at the bump in the middle which part came from where. But if, as we are assuming, the bump is composed of two distinct waves put together, then one has the property of having come from my side and the other from yours. These properties individuate the parts, as well as the waves that emerge. The objector protests, however: It is not just that in practice we can't distinguish one part from another in the bump in the middle. In principle, no characteristics available while the bump exists serve to individuate the parts. This makes a difference, for metaphysical questions—how we choose or how we are objectively well advised to cut up the world into parts—may very well depend, among other things, on what exemplified characteristics there are which could at least in principle serve to individuate the parts. At the very least, we have been given no reason to think this wrong. Given this, and given the absence at the middle bump of individuating characteristics which are exemplified at the moment, it just begs the question to say that the bump's parts are individuated by differences in some historical property. Given the unavailability at the moment of any way of distinguishing the two parts and saying which came from which side, what reason could there be for saying that one part has the property of having come from my side and the other part from yours?

All this ought to seem a bit silly. By this time many readers will want to give these two thick heads a good crack on the skull as the only apparent way to get them to ask, “Why say there are two waves composing the bump in the middle as opposed to two prior waves added together to get a partless whole?” While this is surely the right first response, the issue is actually a bit more complicated, and not restricted to just the bump in the middle. We can understand the situation best if we take a moment to understand what physicists call a Fourier decomposition of a wave process. The simplest kind of wave to describe mathematically is a regular undulation,



Figure 2.

described by the trigonometric sine function, with a whole number of complete wave lengths (the distance from wave crest to wave crest) between the ends of the rope. Such a wave process is characterized by its wave length and its frequency (the number of times in one second a point moves through a complete cycle from high point, to low point and back to its original high point). The rope may exhibit such sine waves with one wave length, two, three, or, indeed any number:

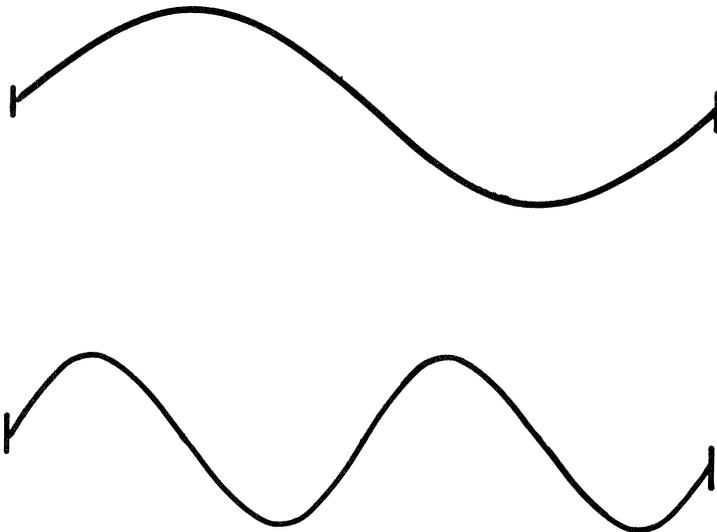


Figure 3.

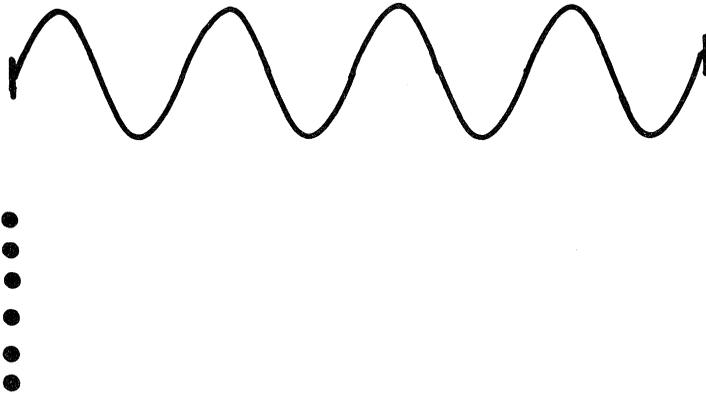


Figure 3 (continued).

The fact that we need is that *any* wave can be described as a weighted sum of these simple sine waves. In particular this applies to our initial example. When we shake the two ends of the rope we set up a system of waves, described by an infinite weighted sum of sine waves, each with its characteristic wave length and frequency. This sum, describing one wave process taking place over time, describes first our two “separate” waves, then the bump in the middle, and finally the two waves which emerge from the middle. When described this way, there is no more reason to count my wave and your wave, as they leave our hands, as separate, than to count the bump in the middle as being composed of two parts.

One could, of course, count each component of the total process as a separate entity, each with an individuating frequency and wave length. But it is important to appreciate that there is nothing unique about such a decomposition. One can similarly analyse such a process into parts in indefinitely many ways. In many respects this is just like the situation with physical objects, which, after all, can be decomposed in indefinitely many ways into physical parts, temporal parts, and combinations of the two. Given collections of the parts, we can stick them back together in various ways, some of which will be well motivated and some not (e.g., me until 1985; Cheryl Tiegs thereafter). Similarly, we can, in various ways, compose parts of the total wave process, or parts taken for parts of the time; and each of these compositions will be sensible or not depending on contextual factors, such as the causal history of the situation. Given the causal history of the original example, it may well make sense to lump together the part of the wave process moving away from my hand, before and after passing through the middle. Given another causal history (smashing the bump in the middle and then quickly jerking the

rope to cause a similar process to continue) such an amalgamation might make less sense. The situation is very similar to that in which two highways, say US 99 and state 120, merge for some distance.

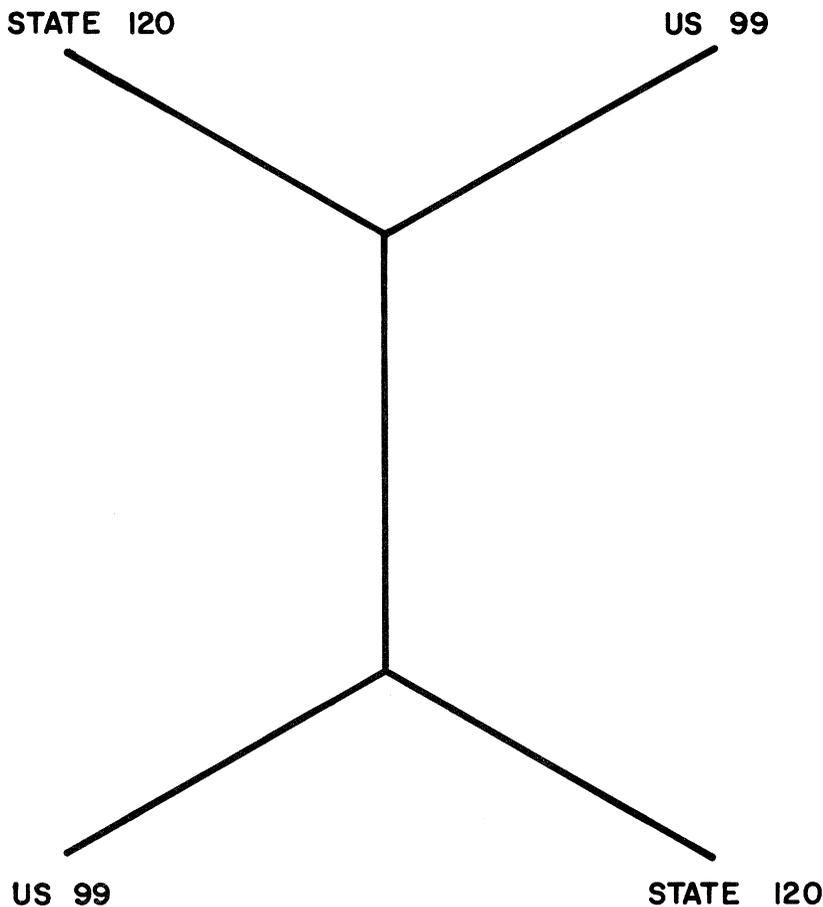


Figure 4.

We sensibly describe the right lower branch and the left upper branch as both parts of the same entity, US 120, given relevant causal history, such as government agency responsible for building, source of funding, and the like. But it would be crazy to say that the joint stretch, US 99–State 120, was composed of utterly indistinguishable parts, which thereby provided a counter example to Leibniz’s principle. (The example is taken from Lewis 1976 p. 27.).

Though my initial example is in itself silly, it serves to bring into focus

some facets of the recent debate on Leibniz's principle. Cortes (1976) proposed a counter example with very much the same structure as my rope trick, but with a great deal greater *prima facie* plausibility because it used particles instead of waves. In place of my bump in the middle he had a two particle state, composed of two particles in exactly the same physical state. Given that the case involved two particles instead of waves, there was much less temptation to say that there was a partless sum, or anything like a Fourier analysis of the situation. Cortes considered and rejected the objection based on historical properties, and Barnette (1978) reacted with the point about confusing metaphysics with epistemology. I won't trouble with the details of their exchange, since I think I have mirrored it very faithfully in the discussion of my example. No one published what corresponds to my reply to the claimed confusion between metaphysics and epistemology, though I think it is a line that Cortes might have consistently pursued.

However, Cortes was able to say what he wanted about two particles because he appealed to a very strange kind of particle—light quanta, or photons (any kind of bosons—e.g., alpha particles—would do). He unblinkingly refers to photons as particles. But are they? Photons are described by quantum theory as having both particle-like and wavelike aspects, and the possibility of a two particle state with both particles in the same state arises only because these “particles” are also “waves”. More specifically, particles in quantum mechanics are described by “state functions” which are wave descriptions. Thus two “particle” states may add up, or superimpose, to form a new state, in just the way that two wave patterns on the rope may merge to form a new whole. We get a two particle state with both particles in exactly the same state only by virtue of a description of state by a wave function which is analysable as two one-particle waves superimposed. It is true that photons also have particle-like aspects. But we have cause for worry here: if a wave description is the appropriate one in this situation, Cortes's example threatens to come undone as a counterexample to Leibniz's principle in exactly the way my rope example came undone.

The issue is a delicate one because no one has been able to squeeze out of orthodox quantum mechanics a really satisfying account of how wave and particle aspects relate within the theory. Perhaps we can do better by turning to our most detailed account of change of particle states, quantum field theory. Indeed, Ginsberg (1981) has already done so in a response to Barnette. Barnette had said that two particles, coming from *A* and *B* respectively and entering identical states at time  $t_1$ , could nonetheless be distinguished during interval *P* by virtue of their historical properties of having come from *A* and *B*.

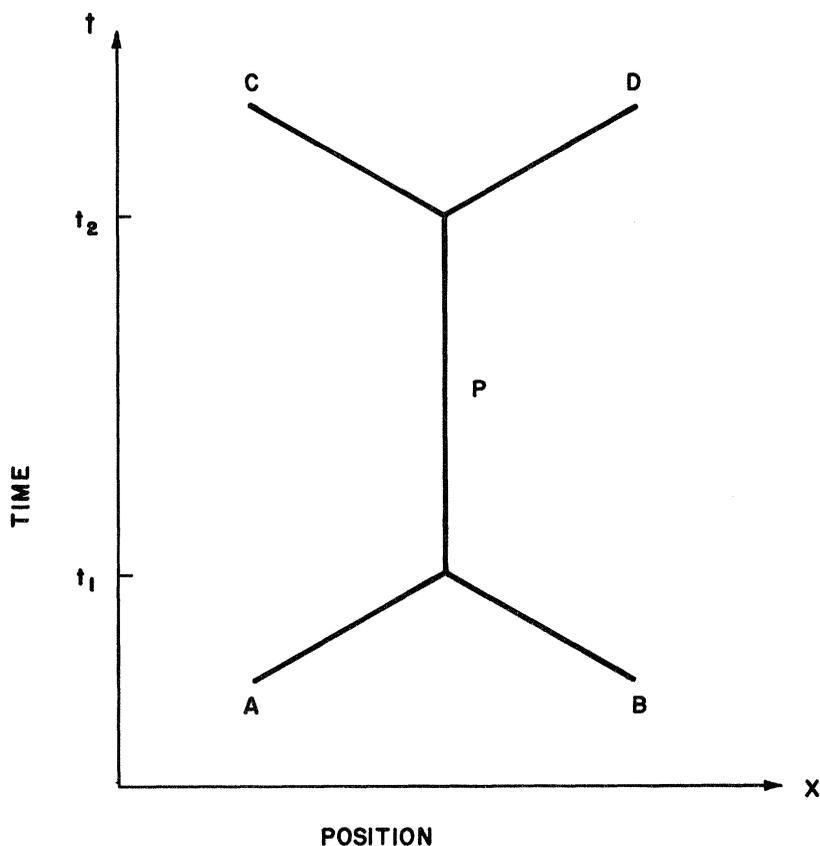


Figure 5.

Ginsberg objects: According to quantum field theory, any change of state is described by so-called creation and destruction operators. Suppose we start with a particle in state 1 and end with a particle in state 2. In quantum field theory this is *always* described by saying that the particle in state 1 is destroyed and a particle in state 2 is created. In particular, at Barnette's time  $t_1$  the two initial particles are destroyed and two new identical particles are created. Since the particles are distinct before and after  $t_1$ , neither particle during  $P$  can have the property of having come from  $A$  and  $B$ . The two identical particles created at  $t_1$  (and we may suppose destroyed at  $t_2$ ) have all their properties in common throughout their whole existences, and so provide a counter example to Leibniz's principle.

There is an initial worry about Ginsberg's argument that has nothing

to do with the mysteries of quantum field theory. As we already noted, we can string together distinct parts in various ways to make wholes. This holds for temporal parts of objects conventionally conceived. We can consider temporal stages as independently existing things to be grouped together in larger individuals in various ways, which ones counting as sensible depending on the circumstances.<sup>1</sup> In fact, we could mimic quantum field theory and describe each temporal state as being “destroyed” just as the next was being “created”. Conversely, the destroyed and created objects of quantum field theory can be grouped together to compose enduring individuals. Indeed, the created and destroyed objects of quantum field theory are, as Ginsberg notes, changeless. So we will have to string them together into larger individuals if we are to describe a world in which anything undergoes change.

But much more importantly, the interpretation of quantum field theory’s creation and destruction operators needs some careful scrutiny. When the theory ascribes operation of one of these operators, *what* exactly is created or destroyed? Physicists almost always say “particles”. But this answer does not do justice to the wavelike aspects of the theory in which quantum field theory indulges at least as much as conventional quantum mechanics. To understand this we need the notion of an excitation of a field. According to quantum field theory, the world can exhibit wave processes. That is, the world is, not exactly a medium, but a situation in which wave states can occur. In more detail, the world can be described as a collection of oscillators. Think of them as individual pieces of rope or string stretched out between pegs, so that each strand can enter into a state of vibration. Unlike the rope of our initial example, however, each oscillator can support wave patterns of only one wavelength and frequency. Now think about one of these pieces of rope, or oscillators on which no vibration is taking place. If we pluck it, it starts to vibrate. We say that it is now in an excited state. Its vibratory state of excitation may be further increased or decreased. Quantum field theory describes the universe as being a collection of such vibrators, with the peculiarity that their states of excitation cannot be changed continuously but only in discrete units. The operation of creation and destruction operators need not be understood as creating and destroying particles, but as increasing and decreasing by one unit the level of excitation of the oscillators that

<sup>1</sup>In some unpublished lectures, Kripke argues that it is a matter of objective fact and not convention which groupings are sensible and which are not, that it is a matter of metaphysics and not just epistemology. To give the barest outline of what I take to be his main argument, consider the old rotating bucket-full of water (which need not be in an otherwise empty universe). Depending on how we put together the time slices, the bucket will come out as rotating or not rotating. But whether or not the water creeps up the side of the bucket is explained by its rotation. The same point can also be made with linear acceleration.

compose the universe or field. These units of field excitation are then called “quanta” of the field or “particles”. These quanta (to try to use a neutral term) are like particles in some of their observational effects and in that they come in discrete units. But they also have all of the wave properties set out in their characterization as field excitations.

Now what happens when, as the particle theorist would like to say, one creation operator operates twice to create “two particles in the same state”? It is at least as good a description to say that the level of excitation of one of the field’s oscillators has been increased by two units. And for all that has been argued, we have no reason not to view this exactly as we did the middle bump in my rope example. We have one total oscillatory state which either should be said to have no parts, or should be acknowledged to be analyzable, in countless different ways, into components which do have individuating characteristics of wave length and frequency. I don’t see that the fact that the level of vibratory excitation can be increased or decreased only in discrete units makes any difference to this conclusion. To give an analogy, suppose I have an account with a money market fund in which I can make deposits and withdrawals only in exact units of \$1,000. On Monday I deposit \$2,000, and on Friday withdraw the same amount. (Do I withdraw the same \$2,000?) If we are to be taken by Cortes’ line of thought we need not go as far as quantum theory for our example. We might as well argue that between Monday and Friday we had two “\$1,000” in exactly the same state and so two things utterly unindividuated by any differences in properties.

The state of these double excitation (“two identical particle”) states is problematic in another respect. To serve as a counter example to Leibniz’s principle, our case cannot be one in which we observe the particles, for there would have to be a difference in time and/or place of observation which would then serve to individuate the “particles”. So the case will have to be an unobserved state. How do these come into the theory? The important case of scattering is really perfectly general for the point at issue. The theory describes scattering of one or more particles which come in “from very far away and very long ago” (space and time taken in the limit of  $-\infty$ ) into a state “very far away and very long from now” (space and time taken in the limit of  $+\infty$ ). What happens in between? The theory describes this as a superposition of all the processes, occurring at all space-time points, which could lead from the input to the output state. So our needed double excitation state only “occurs” superimposed with uncountably many other occurrences of the same and other processes occurring at all possible points in space and time. “Superimposed” here means added together in just the way that component waves add together to make a larger wave process. Exactly the same kind of thing occurs with other uses of the theory, for example in calculating energy levels.

But given that the needed unobserved double excitation state enters the theoretical description only in superposition with uncountably many other states, do we want to say that this state actually occurs? The issue is not just the possibly pedantic one analogous to the question: when you and I shake our ends of the rope, does the rope really exhibit all those infinitely many sine waves into which our wave pattern can be decomposed? The issue is really the same as that of the double slit gedanken experiment: if a particle somehow gets through a screen with two slits, do we want to say that it REALLY goes through the one slit or through the other? The formalism describes the case in terms of a superposition of both cases. And saying that the particle really does one or the other leads to all kinds of interpretive headaches. Saying that the kind of case needed by the purported counterexample really occurs involves making exactly the same problematic move, except that here we have to deal with a superposition of uncountably many states instead of just two.

None of what I have said constitutes a conclusive refutation of claims made by any of the authors whose views I have been examining. My aim has been to call attention to ways in which the issues are more complex and difficult than the prior discussions suggest, and to inch the discussion along by focusing on some of the features of the theoretical situation which are not widely appreciated by philosophers but which must be addressed to make headway. (Ginsberg notes the interpretation of creation and destruction operators in terms of raising and lowering field excitations, but he does not seem to see how this complicates the issue.) I would like to close by mentioning one further aspect of the problem situation which will probably force itself upon us in connection with these issues. Superposition and the obscurity as to when and how objects can be individuated in quantum mechanics suggests some kind of holism. On the one hand, we would like to say that we have two individuable objects, for we describe situations in which something very much like observing two distinct objects can occur. But when the theory describes "two" objects in terms of a superposition, we get into the sort of difficulties discussed throughout this paper, and others, such as those associated with the Einstein, Podolsky and Rosen experiment. The situation is even worse, however, for there is a problem with seeing how any solution to such problems could work. For macroscopic objects, individuation always seems possible. Quantum theory shows that there are problems with the individuation of very small objects. But quantum theory is supposed to apply generally, to the large as well as to the small, and the factors, the presence of which account for the strange behavior of very small things, shade off almost continuously as one moves from small to larger objects. There is no principled way of drawing a line and saying that on one side objects are always individuable and on the other side some kind of holism (of

a kind to be clarified) applies. Possibly one might approach this impass by appealing to probability to build a bridge between the continuous gradations between the big and small on the one hand, and, on the other, the all-or-nothing character of holism and its opposite, which I call pluralism. Two objects are individuatable when one has a property which the other lacks. According to quantum mechanics, two relatively large objects are virtually certain, at any given time, to exhibit distinct properties. The chances for their not doing so may be compared with the chances of all the molecules of the air in this room rushing off into the corner, through a statistical mechanical fluke. But for smaller superimposed objects the chances for exhibiting distinct properties can be less, so that the chances for quantum holism to manifest itself rise to significant levels. Or one might approach the problem through the related issue of how difficult it is to put "two objects" into a superimposed state. This is out of all practicable possibility for even things as big as large molecules, but quite feasible if the objects are small enough.

Anyone who has worked on these problems will know at a glance how hard it will be to fill out these suggestions. At the moment, I put them forward as speculations meant to further whet the appetite for work on what I think are some of the most fascinating interpretive problems we face today.

#### REFERENCES

- Barnette, R. L. (1978), "Does Quantum Mechanics Disprove the Principle of The Identity of Indiscernibles?" *Philosophy of Science* 45: 466–470.
- Cortes, A. (1976), "Leibniz's Principle of the Identity of Indiscernibles: A False Principle", *Philosophy of Science* 43: 491–505.
- Ginsberg, A. (1981), "Quantum Theory and Identity of Indiscernibles Revisited", *Philosophy of Science* 48: 487–491.
- Lewis, D. (1976), "Survival and Identity" in A. Rorty (ed.). *The Identity of Persons*. Berkeley: University of California Press.