

We humans are attracted to fanciful models that are often more exciting than reality; so I agree with Mermin's basic premise. But I cannot always be confident of distinguishing a real property from a fanciful abstraction. In fact, if pushed, I would have to admit I'm not sure what a real property really is. Possibly Mermin can enlighten me.

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David Mermin tells us that our "bad habit" of reifying the quantum state "induces people to write books and organize conferences about 'the quantum measurement problem.' " However, a quantum measurement problem does not arise only from an unfortunate perspective on quantum theory.

A quantum measurement problem, as close to magic as anything in science, is displayed in quantum-theory-neutral experimental observations that assume only the free choice of the experimenters. In the two-slit experiment, one can choose to demonstrate each object concentrated at a single slit or perform the contradictory demonstration, that each object spread over both slits. Facing this dilemma, George Greenstein and Arthur Zajonc note that "even had quantum theory never been invented, these [two-slit] experiments could have been performed, and we would still find ourselves unable to understand them."¹

Quantum weirdness is increasingly misappropriated as a way to buttress pseudoscience. It is a responsibility of physicists to combat such misappropriation. (See our letter in *PHYSICS TODAY*, November 2006, page 14.)

Presenting the intriguing strangeness of quantum mechanics honestly and interestingly by the use of books Mermin might seem to deplore can effectively combat the misuse of the quantum mysteries. Dismissing the measurement problem as merely a bad way of viewing quantum theory abandons a fascinating mystery in physics to the purveyors of pseudoscience.

Reference

1. G. Greenstein, A. Zajonc, *The Quantum Challenge: Modern Research on the Foundations of Quantum Mechanics*, 2nd ed., Jones and Bartlett, Sudbury, MA (2006), p. 124.

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I am that friend of David Mermin's "who was enchanted by the revelation that quantum fields were the real stuff that makes up the world." I plead guilty to reification and offer the following defense.

I started out, as I think we all did, with the notion that there is a reality out there and that space and time are part of it—not just "an extremely effective way to represent relations between distinct events." When I read Arthur Eddington's *The Nature of the Physical World* (J. M. Dent & Sons, 1942) in high school, I learned that reality was not what it seemed—that Eddington's solid writing desk, for example, was mostly empty space. The next step in my understanding of reality came in college when I found that the electromagnetic field offered a more satisfying picture of the world than action at a distance, which even Isaac Newton derided.¹

When I encountered quantum mechanics, of course, everything became confusion. However, along with David, I was fortunate to attend Julian Schwinger's courses at Harvard University just after he had perfected his treatment of quantum field theory.² I sat enthralled throughout the three-year series (1956–59), in which Schwinger developed QFT as a seemingly inevitable consequence of the most basic assumptions.

However, I came away with a different understanding of QFT than David's. I understood that the fields are physical properties of space that are described by field strengths—just as in classical physics, except that in QFT the state of the field at each point is represented by a vector in Hilbert space rather than by a pure number. That use of Hilbert space, which followed naturally from Schwinger's "measurement algebra," allows superpositions of values. The operators in Hilbert space, as I understood it, are mathematical tools that describe the evolution of the state vectors, and they are not to be reified.

When I saw how QFT resolves the paradoxes of modern physics, it became irresistible. The special relativity paradoxes—for example, Lorentz contraction and time dilation—are a natural result of the way fields behave.³ The spacetime curvature of general relativity, which I could never really visualize, does not exist in QFT; the gravitational field equations are equivalent to spacetime curvature for those who can visualize it, but equivalent is not the same as identical.⁴ Finally, the mysterious wave-particle duality of quantum mechanics vanishes; in QFT, reality consists of fields and only fields.

Because QFT is so neglected by the public (and by many physicists), I am writing a book that presents it without equations. A draft copy of the work, *The Theory That Escaped Einstein*, can be found through an internet search. Feedback is appreciated.

For those who can't kick the reification habit, QFT is the way to go. It is the only theory that offers a consistent and visualizable picture of reality. Reifiers of the world, unite! You have nothing to lose but your abstractions.

References

1. H. Boorse, L. Motz, eds., *The World of the Atom*, Basic Books, New York (1966), p. 319.
2. J. Schwinger, *Ann. Phys.* **2**, 407 (1957).
3. J. Schwinger wrote a six-part series on the theory of quantized fields: *Phys. Rev.* **82**, 914 (1951); **91**, 713 (1953); **91**, 728 (1953); **92**, 1283 (1953); **93**, 615 (1954); **94**, 1362 (1954).
4. S. Weinberg, *Gravitation and Cosmology: Principles and Applications of the General Theory of Relativity*, Wiley, New York (1972), pp. vii, 147.

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I am curious to hear David Mermin's view, in light of his May 2009 Reference Frame, of Galileo's condemnation by the church.

That episode is still considered a scandal by most scientists. For example, several physicists cited the Galileo affair as their reason for opposing the visit of Pope Benedict XVI to the University of Rome I ("La Sapienza") last year.

Could we perhaps say that Mermin would agree with those who refuse to recognize any objective truth in physical theories yet support them as useful descriptions of successions of events, thus condemning Galileo's quest for ontologically realistic theories?

Is the proposition that Earth travels around the Sun ultimately a mere calculational device?

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David Mermin points out a "bad habit" that afflicts most humans: mistaking a computational idealization for the real world. That would probably not be intellectually fatal. What can lead to brain damage is to take the real world to be an approximation of the ideal, rather than doing the reverse.

We talk about geometric shapes such as lines, circles, and spheres. Each of

these words conjures up a picture of a perfect line, circle, or sphere. We know that no real line is perfectly straight and no circle can be made without imperfections, however minute. Yet our mental image is of the perfect geometric shape.

So it is easier in most cases for the mind to grasp the ideal rather than the real. Perhaps Nature is punishing us for our bad habit, forcing us to keep burning up CPU time without getting to the end of π . Not falling prey to the bad habit Mermin so beautifully discusses would clear up a lot of smoky haze in the intellectual environment.

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David Mermin criticizes the "reification" of magnetic fields, but he allows that spark chamber trajectories and atomic spectra are real, so why not also accept magnetic fields, ionic lattices, the cosmic microwave background, and so on? And is reification such a bad habit? Intuitive flashes of insight come as much from immersing yourself in the reality of the physics as from holding your nose and manipulating formal symbols. Often, reification leads us in the right direction: I assume Mermin has no plans to revive Mach's crusade against the reality of the atom.

I sympathize with Mermin's desire to distinguish between mathematical abstractions like quantum field operators and solid realities like metals, but by any reasonable standard, magnetic fields are just as real as equally invisible variations in air pressure. Mermin worries that quantum mechanics describes fields—and atoms and everything else—in weird abstract terms, but allowing the weirdness of quantum mechanics to undermine the normal concept of what is real seems like a case of taking a successful theory too seriously, which is just what he was warning us not to do.

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Does David Mermin believe atoms are real?

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Life certainly would have been easier for Albert Michelson and Edward

Morley if only they hadn't reified the ether! Then they'd have been free to do less difficult things than look for evidence of it. After all, it was a perfectly useful abstraction for physicists who thought all waves require a medium.

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David Mermin seems to advocate the view of theoretical paradoxes and controversies of quantum mechanics and field theory as problems of "tools" of a linguistic or otherwise technical nature. His advice is not to "make life harder than it needs to be." First, philosophical reduction of a fundamental science to a human tool goes against the main quest of science – the quest for objective truth about the universe. Second, the suggested advice seems more conducive to peace of mind than to scientific inquiry. Paradoxes and contradictions have always been a rich source of inspiration and contemplation for those who are seeking new knowledge.

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"I hope you will agree," David Mermin writes, "that *you* are not a continuous field of operators on an infinite-dimensional Hilbert space. Nor, for that matter, is the page you are reading or the chair you are sitting in." His comment is a nice example of the logical fallacy known as "appeal to belief": Most people believe X is true, so X is true. That many people believe they are not operators in Hilbert spaces, believe they do have free will, or do or don't believe in global warming makes no difference as to whether a statement is true or false. I have no basis on which to decide what I "really" am. And though I personally think any such argument is a waste of time because it can never be decided anyway, and though I am sympathetic to the opinion Mermin expresses, his article dismisses the relevance of both quantum foundations and the philosophy of science out of hand in a rather polemic and not very insightful way.

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David Mermin cautions against taking our "most successful abstractions to be real properties of our world." I think he has set up a straw man. To me, the