# Highlighting the usefulness of string theory FREE

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explain the behavior of the photon—or any other quantum object, which obeys the fundamental probability rules—leads to the kind of nonsensical question Zukav asks, as the following more familiar example shows.

If you toss 10 coins, the probability of getting 6 heads (60% of the total) is about 0.205. If you toss 10 000 coins, the probability of getting 60% heads is 0.00 . . . 029 (89 zeros)! Now regard the 10 000 coins as 1000 groups of 10 coins. Each group, in isolation, has a 20.5% chance of getting 60% heads, but the presence of other groups renders getting 60% heads practically impossible! As Zukav would state, How does each group "know" whether the other groups are present? Perhaps the coins are conscious!

## Spirit = $mc^2$

The number-one word borrowed from physics and abused in the woo literature is "energy." Positive and negative, healing, karmic, and qi are just a few examples of "energies" adrift in the sea of mysticism. There would seem to be a good reason for that: Energy is nonmaterial, and the most famous equation in physics, $E = mc^2$, equates it to mass, which *is* material. So the equivalence of the nonmaterial spirit or soul with matter, which is at the heart of mysticism, is only one small step away.

But is energy really nonmaterial? Energy is a property of matter. For example, kinetic energy is the energy associated with the velocity of an object. Asking whether kinetic energy is material is as absurd as asking whether velocity is material. Velocity is a property of matter in motion. A red apple is material. Does it make sense to say that redness is nonmaterial? This confusion of matter with one of its properties—energy—is both a common trap into which even trained physicists can fall[4] and a dangerously effective tool that quack scientists use to promote their woo.

The most tantalizing example is when $E = mc^2$ is applied to matter–antimatter annihilation, in which matter transforms completely into "pure energy." However, the "$E$" on the left is the property of some material particles—which, by the way, can be massless, like photons. A photon that strikes an electron and changes its state is as material as an incident electron that does the same thing. Indeed, Eugene Wigner proved that a material particle is described by its mass and spin, each of which could be zero.[5] And that fact is on as firm a foundation as special relativity.

The "$E$" of $E = mc^2$ is *always* the energy of two or more particles that can either produce the mass on the right by binding themselves together or be produced by the mass as it decays. There is no instance in nature in which mass transforms into energy (or vice versa) without some material particles carrying that energy. There is no connection between soul–matter equivalence of mysticism and energy–mass equivalence of modern physics.

## Implications for science literacy

Pseudoscience is a societal mental disease too powerful to be fought in the public arena. The media—the public's main source of information—are more interested in what is popular than in what is right. However, behind the relative protection of classroom walls, we have an opportunity to reach the future citizenry and thus a hope that our grandchildren and their children will not succumb to the irrationality that has afflicted our generation.

In high school or in introductory college physics or chemistry courses, a five-minute weekly (extra-credit) quiz based on a 30- to 45-minute reading assignment can go a long way in making students aware of pseudoscientific nonsense and its danger to society. I suggest the encyclopedic resource http://rationalwiki.org as a starting point. Such training may not be as urgent as climate change, in which many teachers are admirably engaged. But the consequences of pseudoscience are too menacing to be ignored. And the classroom is the only place where it can be challenged effectively.

## References


1. M. Beauregard et al., *Explore* **10**, 272 (2014); E. Mielczarek, B. Engler, *Skeptical Inquirer* **37**(3), 32 (2013).
2. D. Pruett, "Toward a post-materialistic science," The Blog, Religion, *Huffington Post* (1 October 2014); S. Hassani, *Skeptical Inquirer* **39**(5), 38 (2015).
3. S. Hassani, *From Atoms to Galaxies: A Conceptual Physics Approach to Scientific Awareness*, CRC Press/Taylor & Francis (2010), p. 328.
4. A. Hobson, *Am. J. Phys.* **81**, 211 (2013).
5. E. Wigner, *Ann. Math.* **40**, 149 (1939).



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# LETTERS

# Highlighting the usefulness of string theory

Although Edward Witten does an admirable job explaining why the mathematical structure of string theory is quite beautiful (PHYSICS TODAY, November 2015, page 38), I think he overstates the evidence that "string theory potentially unifies gravity with the other forces of nature." In particular, it is unclear whether string theory provides a natural explanation for supersymmetry breaking or the observed properties of elementary particles. In addition, string theory has yet to explain how the unphysical predictions of classical general relativity are eliminated; for example, how the unphysical features of the interior Kerr metric—which describes the spacetime inside the event horizon of a rotating black hole—are eliminated in the course of the gravitational collapse of massive rotating objects.

It is true that string theory has provided a nice model, the anti–de Sitter/conformal field theory (AdS/CFT) correspondence, for the nature of spacetime just outside an event horizon, but to date string theory has had nothing definitive to say about the nature of spacetime inside an event horizon. A related problem for string theory (and also for classical general relativity) is that it provides no explanation for what the universe looked like prior to the Big Bang, which is unexpected if string theory really provides an underlying quantum theory of elementary particles and gravity.

I completely agree with Witten that two-dimensional CFT is likely to have a critical role in any fundamental theory of spacetime. However, because of the obvious importance of four dimensions in the real world, it seems much more likely that


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four-dimensional curved twistor spaces[1] rather than strings play the role of fundamental objects.[2] This, I submit, is an even more beautiful idea than string theory.

## References


1. R. S. Ward, R. O. Wells Jr, *Twistor Geometry and Field Theory*, Cambridge U. Press (1990).
2. G. Chapline, K. Yamagishi, *Phys. Rev. Lett.* **66**, 3064 (1991).



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Counting myself among "every physicist"—and an old one at that—who has been awestruck with the complexity and power of string theory but not having dabbled actively in field theory for some time, I had high hopes that the amazing Ed Witten would help me understand it better. Instead, I came away with a moderately stiff neck from straining to hear the "rhymes" of the theory. And I must confess that the references to "diffeomorphisms" reminded me of "sexual dimorphism," something comparable to mathematical gender equality, if that's possible.

More seriously, I was disappointed that Witten did not discuss what a lot of us would really like to know: Is string theory—can it ever be—falsifiable? What, if any, are its applications in the physical world? Who is working on these aspects of the problem? Is it really "not even wrong," as Peter Woit's book by that title (Basic Books, 2006) notes?


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▶ **Witten replies:** In my article I tried to explain in a succinct way some of the exciting highlights of string theory, and I assumed for readers only a basic comfort level with Feynman diagrams and general relativity. The points in question should be widely understandable, but I am not sure where they have been explained in quite as elementary yet substantive a way as I aimed for.

I certainly did not claim that everything has been understood; there are plenty of unsolved problems, as George Chapline points out, and that is one reason that the subject remains exciting. It was not possible in a short article to explain all the fascinating things that have been discovered and the many interesting ways that string theory interacts with other topics in physics and mathematics. Some of that has been covered in the past in other articles in PHYSICS TODAY (see, for example, the article by Steve Giddings, April 2012, page 30, and the Quick Study by Hong Liu, June 2013, page 68).

I have worked on the specific subject of twistor theory quite a lot, as Chapline probably realizes. Actually, one reason that I suspect string theory is on the right track is that when critics have had good ideas—whether involving black hole entropy, noncommutative geometry, or twistor theory—those ideas have tended to be absorbed into string theory.

I regret that Peter Hansen did not find my article compelling, and I hope other readers thought otherwise. Many circumstantial clues suggest that string theory is on the right track. If that is the case, it is reasonable to hope that it will become clear, probably through a combination of theoretical and observational progress.


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