

Commentary

The dangerous growth of pseudophysics

Pseudoscience has been rapidly growing in the past few decades. Dietary supplements and homeopathic preparations advertised by various media charlatans constitute a multibillion-dollar industry. And the internet is awash with self-proclaimed experts who have gathered armies of uninformed citizens, ready by the hundreds of thousands to sign petitions to force their antiscientific demands on the food and agriculture industries.

Major universities, including Harvard, Yale, and Stanford, house centers of integrative health, which offer courses in acupuncture, Reiki, qigong, and Vedic medicine and are funded by the National Institutes of Health. Elsevier, a reputable scientific publisher, now offers *Explore*, a journal devoted to the pseudoscience of alternative and integrative medicine. In 2014 it published "Manifesto for a post-materialist science," which elevates parapsychology and near-death experience to the rank of quantum theory (QT).¹ And the influential *Huffington Post* glorified the authors of that manifesto as mavericks on a par with Nicholas Copernicus, Johannes Kepler, and Albert Einstein.²

Among the factors contributing to the rapid growth of pseudoscience are various misrepresentations of modern physics and especially of QT. Some prominent physicists of the past century have presented philosophical outlooks that, as mystical and antiscientific as they may be, have become wrongfully associated with modern physics. And the public's scant knowledge about the underlying principles of science, combined with the compelling power of science exhibited in smartphones, GPS, and confirmation of the Higgs boson and gravitational waves, turns those philosophical misrepresentations into a forceful engine for promoting such nonsense as quantum healing, quantum touch therapy, and other "quantum" commodities sold in the crowded information marketplace.

I offer two important examples of

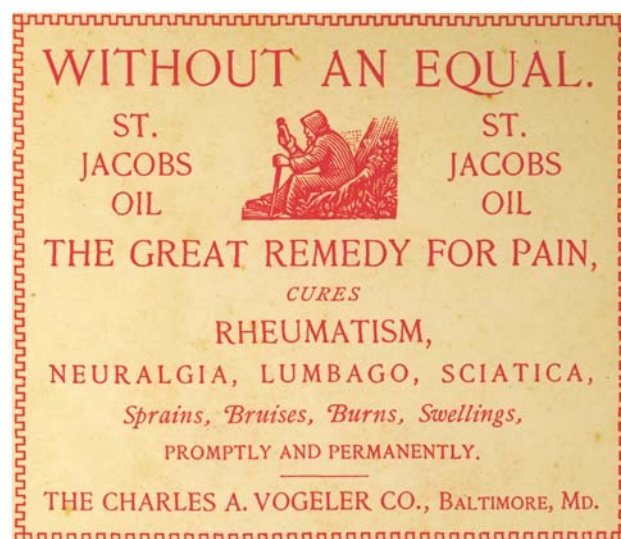
misrepresentations of modern physics: the double-slit experiment and $E = mc^2$.

Conscious photons?

The entire nonrelativistic QT is based on two fundamental assumptions about ψ , the solution of the Schrödinger equation. The first is that the square of the absolute value of ψ is the probability of the state of a system. The second assumption is the superposition principle: If there are several paths available to the system, the total ψ is the appropriately weighted sum of the ψ s for each path.

Those two assumptions have been the source of much confusion and abuse since the inception of QT. Unfortunately, the fire of abuse was ignited by some of the very people who created the theory. (See the article by Mara Beller, *PHYSICS TODAY*, September 1998, page 29.) That early origin encouraged future generations of abusers to fan the fire in the 1960s and 1970s. Turn to any page of a book purporting to establish a parallel between Eastern mysticism and modern physics—for example, Fritjof Capra's *The Tao of Physics: An Exploration of the Parallels Between Modern Physics and Eastern Mysticism* (Shambhala, 2010) or Gary Zukav's *The Dancing Wu Li Masters: An Overview of the New Physics* (William Morrow, 1979)—and you are likely to find a sympathetic quote by Werner Heisenberg, Niels Bohr, or J. Robert Oppenheimer.

One source of mystical delight is the familiar double-slit experiment in optics.³ In *The Dancing Wu Li Masters*, Zukav



IN THE 1890s the sale of highly questionable potions and elixirs was common, as shown in this advertisement from 1892. In the 21st century, the snake oil salesman has a new face: Mysticism of many varieties is dressing itself up by appropriating and misusing terms and concepts commonly understood in physics. (Image from Wikimedia Commons.)

imagines doing the experiment twice, first with one of the slits closed, and second with both slits open. He wonders,

How did the photon in the first experiment know that the second slit was not open? . . . When we fired our photon and it went through the first slit, how did it "know" that it could go to an area that must be dark if the other slit were open? . . . There is no definitive answer to this question. Some physicists . . . speculate that photons may be *conscious*! (page 62)

Zukav's repeated use of the word "know" already hints at an intelligent photon!

Despite Zukav's claim, there *is* a definitive answer to his question. The difference between the two scenarios arises not because the photon has some mystical knowledge but because ψ is a superposition of all possible paths—one path if only one slit is open and two paths if both are open.

Squaring the absolute value of the ψ for one path leads to a probability distribution that is different from that of two paths; the latter leads to the appearance of light and dark bands. Any attempt to

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 non-material, 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 non-material? This confusion of matter with one of its properties—energy—is both a common trap into which even trained physicists can fall⁴ 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

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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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