Richard Kadel misuses the meaning of "theory" as applied by most scientists today. Theory as used today hardly means "speculation based on incomplete knowledge." In *Teaching About Evolution and the Nature of Science* (National Academy Press, 1998, available at http://www.nap.edu/readingroom/books/evolution98), a theory in science is defined as "a well-substantiated explanation of some aspect of the natural world that can incorporate facts, laws, inferences, and tested hypotheses." Laws are "typically descriptions of how the physical world behaves under certain circumstances."

There is no suggestion that either is more certain than the other. In fact, when I teach my geology, physical science, and Earth science students about the scientific method, I stress that both laws and theories are as certain as we can make them, both are testable, and in the light of new evidence, both can be modified, overturned, or replaced. The big difference is that a theory is usually explanatory, while a law is usually descriptive and often quantifiable.

To define a theory as speculation is to fall into the trap that many nonscientists have fallen into when dealing with such controversial theories as evolution. There are generally enormous amounts of data to support theories and laws. Without that data, we usually refer to "hypotheses" to suggest the greater degree of uncertainty. In fact, most laws and theories start out as hypotheses.

I do agree that Einstein's formulations should be called laws. However, that's not because they are more certain now; it's because they are quantifiable and descriptive. But we still need to refer to Einstein's theories as well, because they explain why the formulations work.

Gregory Mead
(greg.mead@sfcc.edu)
Santa Fe Community College
Gainesville, Florida

Isaac Newton offered us his laws of gravity, describing the attractive force between masses, but refused to offer a theory. Instead, he famously stated, "I have not been able to discover the cause of those properties of gravity from phenomena, and I frame no hypothesis. . . . It is enough that gravity does really exist, and acts according to the laws which we have explained.''

An attempt to boost the status of special relativity by referring to it as a law rather than a theory would actually have the opposite effect of demoting Albert Einstein's astonishing contribution. He didn't describe his (or anyone else's) observations, he described and explained real phenomena before anyone even knew they were there.

Joseph Ribaudo
(jribaudo@ucsd.edu)
Scripps Institution of Oceanography
University of California, San Diego
La Jolla

Albert Einstein used the term "principle of relativity." My dictionary defines a principle as "a fundamental law that describes how a thing moves, works, or acts," which seems quite appropriate. Perhaps we would honor Einstein best by using his own words.

I actually prefer the word "theory" despite the pejorative view held by the general public. It reminds us that scientific theories cannot be proved, but only disproved. We always exist in a state of incomplete knowledge. When someone says to me that evolution is only a theory, I like to point out that gravity is also a theory, and a very useful one at that.

Lewis E. Wedgewood
(wedge@uic.edu)
University of Illinois at Chicago

Kadel replies: Vladimir Krasnopolsky writes that special relativity has several authors and specifically mentions publications by Hendrik Lorentz that were earlier than Einstein's 1905 paper. One reader wrote to me indicating the contributions of Henri Poincaré, and interested parties can find a summary of Poincaré contributions, with accompanying references, on Wikipedia (http://en.wikipedia.org/wiki/Henri_Poincar%C3%A9#). Evidently, he promoted Lorentz's work and, before 1905, promulgated the "principle of relativity" and an early form of $E = mc^2$ regarding the properties of emitted radiation. Recollecting from my undergraduate education, I believe it is correct to state that Einstein was the first to derive special relativity without reference to electromagnetism and the first to write down what we sometimes call the equivalency of mass and energy, or what I referred to in my previous letter as Einstein's third law.

An internet search on "Einstein's laws" returned hundreds of websites that use precisely that terminology when referring to special relativity. Included among them is the "Laws of Science" (http://en.wikipedia.org/wiki/List_of_laws_in_science), which has the energy of photons, special relativity, and general relativity all under Einstein's name. So it's hard to be original, and the general public may be ahead of us—or at least me—in this discussion.

I exchanged private e-mails with Helen Quinn shortly after our writings appeared in the same issue of PHYSICS TODAY. She wrote that her "impression is that the idea of a law became archaic right about the time it was realized that Newton's laws were not absolutely true in all circumstances. But we never gave up using the term for ideas that had already been blessed with that language usage." She asked, as does William Hooper, who would decide, and whether some international body of physicists should be empowered to promote theories to laws, just as the International Astronomical Union declared that Pluto is not a planet. I agree with that proposal, but I'll caution that Pluto is still a planet to me.

Hence, I make my own prejudice clear as to theories versus laws. Unlike Gregory Mead, Joseph Ribaudo, or Lewis Wedgewood, I find the idea of a law much more compelling than a theory. In my own corner of physics—elementary-particle or high-energy physics—we have, for example, string theory and supersymmetry theory. Although both propose solutions to perceived problems with the standard model of high-energy physics, neither has made a prediction that has yet been verified by experiment. (My theoretical colleagues will disagree, and they will happily point out that in supersymmetric theories, in which every quark, lepton, and gauge boson we currently know acquires a new partner, about half of the supersymmetric particles have already been discovered. Some may argue that the observation of "dark matter" is actually the detection of supersymmetric particles, but to me the connection has not yet been made.) Furthermore, in casual conversation, private thinking, or everyday life, one frequently hears—or asks—the question, "Does it violate the laws of physics?" I've never heard "Does it violate the theories of physics?" I vote for the laws of special relativity, and in deference to history and the input from readers of my letter, let a duly organized body of physicists assign attribution, lest others do it for us.

Richard W. Kadel
(rwkadel@lbl.gov)
Lawrence Berkeley National Laboratory
Berkeley, California

Language of science II: Degrees of knowing

Helen Quinn (PHYSICS TODAY, January 2007, page 8) makes a very good point that the general public often misunderstands the meaning of "belief" and "theory" as used by scientists. The problem originates, I believe, in the way science is taught in the schools. As Thomas Kuhn noted long ago in *The Structure of Scientific Revolutions* (University of Chicago Press, 1962), science is taught like religion: You'd better believe it or you will get a bad grade. Fundamentalists opposed to evolution have a stronger threat: You'd better not believe it or you will go to Hell.

Today, as a result of the No Child Left Behind Act, US public schools place increased emphasis on testing. Unfortunately this motivates teaching to the test, with little emphasis on the scientific method.

The most important thing to be taught is how scientists have come to believe the present theories, usually after a long struggle, as a result of many experiments and observations. Even for a limited part of physics, it is hard for a student to recapitulate in a semester what may have taken scientists many years to discover. There is always an attempt to cover too much material, as evidenced by the weight of the latest university physics textbooks, which only the stronger students can lift. There is no simple solution, but it is important to identify the problem.

Lincoln Wolfenstein
(lincolnw@andrew.cmu.edu)
Carnegie Mellon University
Pittsburgh, Pennsylvania

Thank you, Helen Quinn! Many physicists need your reminder to watch some of the words we use in our discussions. As teachers, we must be especially careful; and when we talk with nonscientists, it may well be necessary to explicate exactly what we mean by certain words. The majority of the population is not even aware of the incorrect meanings so many people attach to so many significant words.

The recently renewed debate on biological evolution provides a wealth of glaring examples. People often misuse words in important discourse. As a hopefully extreme example, I recall the claim: "I know that God exists, but science is only a bunch of theories." At the same time, people enjoy the use of the most sophisticated gadgets that recent science and technology has made available.

I suggest that the understanding and distinction of the correct meaning of words such as knowledge, belief, hypothesis, and scientific theory must be an essential part of education. It should be taught in all high schools—if not in