

Readers Elaborate on Fashion and Truth, Fact and Theory

Congratulations and thanks to Michael Riordan for his Opinion piece “Science Fashions and Scientific Fact” (PHYSICS TODAY, August 2003, page 50). He has identified a dangerous tendency of some physicists to divorce the truth of an idea or theory from its experimental verification. And he has, I hope, done so early enough that this tendency can be nipped in the bud. However, the confusion leading to the state of affairs that he identified is deeply rooted and part of a broader issue. It has been displayed more than once in the pages of PHYSICS TODAY (see June 2002, page 48, and September 2002, page 10), where we have read, for example, that science need not concern itself with truth but only with theories that are of interest to scientists.

If we could understand that science involves the establishment of facts, then assertions about its lack of relation to truth would be seen immediately as entirely vacuous. I urge that we dismiss the idea that scientific fact is somehow different from other kinds of fact. That the Ptolemaic Earth-centric system is false and the Aristarchean heliocentric system is basically true is a fact, as much scientific as ordinary. That microbes and not “vapors” cause disease is a fact. That Earth is billions and not thousands of years old is a fact. And there is no essential distinction between fact and truth.

Famous scientists may have contributed inadvertently to the confusion. For example, Arthur Eddington wrote:

We cannot pretend to offer proofs. *Proof* is an idol before whom the pure mathematician tortures himself. In physics we are generally content to sacrifice before the

lesser shrine of *Plausibility*.¹
(italics in the original)

Albert Einstein had this comment:

The sense-experiences are the given subject matter [of science]. But the theory that shall interpret them is man-made. It is the result of an extremely laborious process of adaptation: hypothetical, *never* completely final, *always* subject to question and doubt.²
(italics added)

If we follow Eddington or Einstein, it would seem that scientific fact is somehow inferior to ordinary fact, since ordinary, everyday fact is not normally in doubt.

The solution to the confusion lies in establishing a clear distinction between scientific theory and fact. The scientists quoted describe a necessary attitude of skepticism toward theories and provide a stern warning against *believing* our theories. But the aim of every scientific theory should be, and normally is, to rise to the status of fact, or, in other words, to have its truth proven beyond doubt—a process that may take decades or millennia. Riordan offers an example of the process with his brief review of subatomic particle theory. The same point can be made with innumerable other examples from all branches of science. Riordan also cautions that some theories may be inherently incapable of ever becoming facts; such theories should be thought of as providing merely a convenient description rather than an explanation.

As long as a theory remains a theory, Einstein’s “never” and “always” are to be heeded. But when the theory becomes a fact, doubting it is no longer productive; our skepticism will then be a sign of ignorance. Physicists must not blur the distinction between theory and fact. “Scientific fact” should henceforth indicate simply a fact uncovered by science, not essentially different from other facts.

References

1. A. Eddington, *The Nature of the Physical World*, Cambridge U. Press (1928, 1948), chap. 15.

2. A. Einstein, *Out of My Later Years*, Carol Publishing Group, New York (1995), chap. 14; reprinted from *Science* **91**, 487 (1940).

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Michael Riordan makes a good point: If a theory does not eventually lead to testable consequences, theorists are doing metaphysics, not physics. Max Planck used different phrasing to express the same idea: “Experiments,” he said, “are the only means of knowledge at our disposal. The rest is poetry, imagination.”¹

Riordan also suggests that all we are doing is reading the Book of Nature. That image is very powerful, but it cannot be literally correct. If it were, that book would already have been written, a finished work in minute detail. But the book is not finished: Scientists can demonstrate experimentally that we are also inside the book, “through our choices,” as Niels Bohr liked to say.² Consequently, we need to move on the razor’s edge by leaving the relativist and postmodernist positions on the one side, and the easy but unreal image of the finished book on the other side, but equidistant.

Including ourselves in the picture creates a serious problem—that is, how to determine the essence of scientific truth, as Riordan says, and how to explain that physics is, nevertheless, objective. Objectivity and truth can be reached in a participatory universe,³ through different experiments converging in the same result. Let’s look at an example.

The Planck constant h can be experimentally determined by many different procedures that are, in principle, independent of each other. Nevertheless, the experiments all converge in the same value of h (allowing for experimental errors). The probability of this convergence happening by chance tends to zero as the number of experimental procedures increases. This is even more dramatic, given that h is related to some other quantities—for example, the electron charge and mass and the velocity of light. These quantities are also built up by independent

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confluence that constrains their respective values.

In the history of physics, when three or four independent experimental procedures achieve the same result, with none opposing, that result is considered to be a fact. Such confluent relations are then fundamental and permanent; despite nature's being a participatory book, they are the precise points in which objectivity and truth enter into physics.

References

1. M. Planck, quoted in R. Dunbar, *The Trouble with Science*, Faber & Faber, London (1995), p. 12.
2. N. Bohr, *Atomic Physics and Human Knowledge*, Wiley, New York (1958).
3. For further discussion, see J. A. Wheeler, *At Home in the Universe*, American Institute of Physics, New York (1992).

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Arthur Eddington, in his book *The Philosophy of Physical Science* (U. of Michigan Press, 1958), posed the question whether Ernest Rutherford had found or manufactured the atomic nucleus. If he were still alive, I suspect Eddington would be asking a similar question about quarks. The kind of approach to physics that concerns Michael Riordan was alive and well before World War II and was not without its critics then.

Herbert Dingle, philosopher and historian of science, wrote a *Nature* article entitled "Modern Aristotelianism,"¹ in which he attacked the ideas of P. A. M. Dirac, Eddington, and E. Arthur Milne, for many of the same reasons as Riordan attacks what he calls Platonic physics. Dingle's article provoked many responses.² Omitting the three from the people criticized, the replies were roughly equally divided for and against Dingle's point of view. Eddington's belief that dimensionless ratios of the constants of nature could be deduced by pure reason was, of course, part of Dingle's target. That belief is sometimes thought of as the preoccupation of Eddington's old age, but in 1937 he was only in his fifties. And the correspondence is evidence that he was not alone in thinking along those lines, even if he did pursue the idea more single-mindedly than others did. Perhaps this alternative kind of science will be ever with us.

References

1. H. Dingle, *Nature* **139**, 784 (1937).
2. See ref. 1, pp. 997 and 1025.

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Michael Riordan appropriately concludes his Opinion piece by quoting Galileo: "Philosophy is written in this great book, the Universe, which stands continually open to our gaze." But, perhaps to maintain his antitheoretical tone, Riordan withholds from us Galileo's next, and I think crucial, sentences: "But one cannot understand this book if one did not learn how to understand the language, and does not know the characters in which it is written. It is written in the language of mathematics. . . . Without [mathematical concepts] it is impossible for us to understand a single word of it."

Few sane people would quarrel with Riordan's main point that the essential criterion for a theory's acceptability is that it have predictive power. That means, first, that it should be experimentally verifiable or contradictable, and second, that it should encompass phenomena or events that are extensions of ones already encompassed. Riordan overlooks the second point.

Surely, though, predictive power is not the only acceptability criterion. A good theory must also be systematic, comprehensible, attractive—even beautiful. Although it would be disastrous if, as Riordan fears, some people suggested that "mathematical beauty, naturalness, or rigidity . . . should suffice," an equally grave error would be to discard such properties in assessing the acceptability of a theory. We are well advised to listen to Albert Einstein, who said, "A theory is acceptable to us only if it is beautiful." And P. A. M. Dirac added, "Einstein introduced the view that something that is beautiful mathematically is bound to be correct physically. The proof [of a complex theory] comes not really from experiments. The real foundations come from the beauty of the theory. . . . It is the essential beauty of the theory which, I feel, makes us believe in it." Henri Poincaré said, "Science is useful because it is beautiful." Such statements may sound exaggerated, but science is not here only to discover isolated facts. It always was and should remain an inspiration to and enrichment of the human spirit and

a means to discover the overall structure of events, not just facts, as Eugene Wigner emphasized.

An interesting example of how criteria other than experimental verification are also essential for scientific progress is the following: Often it happens that one has a fine theory, but that new observations or experiments reveal phenomena that cannot be encompassed by the relevant established theory. One then tries to accommodate new "facts" by adding extraneous elements to the beautiful theory. But such patching up, although successful, makes the entire edifice ugly. More often than not, that ugliness is a sign that the underlying theory is incorrect. A completely new conceptual beginning becomes necessary, and eventually, a new beautiful theory will emerge—to be tested by utterly new suggested experiments. This example also illustrates well the interplay between experiment and theory, which Riordan seems to see rather one-sidedly. He suggests, perhaps unwittingly, that the main role of experiments is to disprove erroneous theories.

Murray Gell-Mann was certainly right when he insisted that his quarks are just mathematical entities. After all, his SU(3) *flavor* quarks (with only three flavors, *nota bene*) and broken symmetry have very little to do with the physical, unbroken SU(3) *color* quark symmetry. The quark picture of matter became possible only after Y. Nambu and others came to the idea of color as a purely theoretical consideration to reconcile the possible quark picture with the spin-statistic theorem. Even that was not enough to accept quarks as physically real. The entirely theoretical edifice of renormalizable quantum chromodynamical field theory had to be developed first. Riordan disregards those facts in the discovery of quarks and overemphasizes the role of the beautiful deep inelastic scattering experiments. These experimental results indeed led Richard Feynman to the idea of pointlike entities inside nucleons; but partons are not quarks.

Finally, I can't see how the unexpected experimental discovery in 1974 of the J/ψ meson was, as Riordan put it, "Nature's slap in the face, which finally made physicists sit up and admit that quarks truly existed." That discovery merely showed that there is at least one more flavor than in the Gell-Mann–Zweig scheme, so that instead of the SU(3) flavor group, perhaps an