LETTERS *(continued from page 13)*

acceptance speech, Val Fitch said, "It is difficult to give a better example of the mutually complementary roles of theory and experiment than in telling the story of the neutral K meson," which culminated in the discovery of *CP* violation.[1] In fact, one of the main aims of this experiment was to test the theoretical proposal of Lev Landau and others that *CP* is conserved in the weak interactions.

"The theoretical establishment was again confounded by the discovery of scaling," Lipkin continues. This is correct, but he fails to point out that this discovery was made possible because a theorist, James D. Bjorken, suggested plotting the inelastic electron scattering data using a scaling variable that he had introduced earlier on.[2]

Lipkin also claims that "the discovery of two kinds of neutrinos was also motivated not by theorists," but this is incorrect. The search for a second neutrino was motivated by a theoretical puzzle that was first pointed out by theorist Gerald Feinberg: The muon does not decay into an electron and a gamma ray as expected from a single neutrino hypothesis.[3] Subsequently, theorists predicted the existence of a third neutrino, the tau neutrino, which apparently has now been observed at Fermilab. Indeed, the only example given by Lipkin in which theoretical guidance did not play a direct role was the unexpected discovery of the J/psi. There are other such examples, notably Martin Perl's discovery of the tau lepton,[4] but their existence does not support Lipkin's broad generalization that "theorists are often irrelevant."

Seeking the answer to Lipkin's question, "What guides their [experimenters'] explorations?" one needs to look no further than the accounts given by the discoverers themselves, who invariably acknowledged the important contribution of theorists.[1–4]

References

1. V. L. Fitch, in *Nobel Lectures,* World Scientific, Singapore (1992), p. 594.
2. H. W. Kendall, in *Nobel Lectures,* World Scientific, Singapore (1992), p. 694.
3. M. Schwartz, in *Nobel Lectures,* World Scientific, Singapore (1992), p. 469.
4. M. Perl, in *The Rise of the Standard Model,* L. Hoddeson, L. Brown, M. Riordan, M. Dresden, eds., Cambridge U. Press, New York (1997) p. 79.

MICHAEL NAUENBERG
(michael@mike.ucsc.edu)
University of California, Santa Cruz

The issue of PHYSICS TODAY with Harry Lipkin's provocative letter, "Who Ordered Theorists?" arrived by chance at the time I was reading Brian Greene's *The Elegant Universe: Superstrings, Hidden Dimensions, and the Quest for the Ultimate Theory* (Vintage Books, 2000) in which the author tells of the promise and excitement of string theory. Reading such dissimilar views about theory and experiment induces me to comment on an older theorist–experimentalist matter that Greene brings up in his survey of pre-string physics. He states: ". . . Maxwell's theory showed, quite unexpectedly, that electromagnetic disturbances travel at [the speed of light]" (p 24).

This statement about electromagnetic waves falling out of theory is exactly as it was presented to me nearly 50 years ago, and seems to me to be nearly universal, so there is no reason to criticize Greene for it. Yet the facts are just the opposite. Maxwell knew that his equations had to produce wave-like solutions because in 1856, W. Weber and F. Kohlrausch[1] had measured the ratio of electrostatic to electromagnetic units, a quantity known from dimensional analysis to be a velocity, and had found it equal to the velocity of light. In the experiment, a Leyden jar of known charge capacity had had its potential determined by an electrometer, thereby establishing its charge in electrostatic units; it was then discharged through a ballistic galvanometer calibrated in magnetic units.

Michael Faraday had shown a bit earlier that polarized light was affected by magnetism, furnishing a hint that light and magnetism were related, but this new result went far beyond a hint. Its significance was hardly lost on Maxwell, who wrote, "We can scarcely avoid the inference that light consists in the transverse undulations of the same medium which is the cause of electric and magnetic phenomena."[2] His manipulation of the equations that described the laws of Gauss, Faraday, and Ampere had a definite goal, one that forced the bold assumption he made.

Books on electricity for the last decades of the 19th century referred frequently to the Weber and Kohlrausch experiment, which was often reproduced as experimental techniques improved, but when electricity and magnetism began to be taught as derivative from Maxwell's equations, the significance of the experiment was lost and the implication grew that it was all the consequence of a desire for symmetry. The replacement of gaussian by SI units removed *c* from its rightful place, and the trip to the memory hole was complete.

References

1. See J. C. Maxwell, *A Treatise on Electricity and Magnetism*, (article 771). Oxford, England, Clarendon Press (1892).
2. C. W. F. Everitt, *James Clerk Maxwell: Physical and Natural Philosopher*, New York, Scribner's (1975) p. 99.

LOUIS BROWN
(brown@dtm.ciw.edu)
Carnegie Institution of Washington
Washington, DC

LIPKIN REPLIES: The Dirac equation marked the end of an era when the trail to new physics was blazed by theorists. It was followed by a new era during which trails were blazed by experimenters, with theorists trying to explain puzzling "who-ordered-that" results: beginning with the puzzling number 137, the anomalous magnetic moments of the proton and neutron, and the discovery that the muon did not behave like Hideki Yukawa's meson. Another era began many years later with the discovery of neutral currents, charm, and the rise of the Standard Model.

My letter referred to the period between the Dirac equation and the rise of the Standard Model. I therefore do not discuss other periods. However, I note that the conclusion that matter is not continuous but consists of atoms and molecules was settled once and for all because of the extraordinary agreement in the values of Avogadro's number obtained by many different experimental methods.[1] Scientific progress did not result from experiments designed to check theory.

P. A. M. Dirac's goal was to find a description of the electron consistent with both relativity and quantum mechanics. The unexpected spin-off was a remarkable combination of "who-ordered-that" theoretical consequences: the spin and magnetic moment of the electron, the existence of the positron, and all the correct descriptions of electron–positron annihilation and pair creation.

No theorist has since found anything comparable to the Dirac equation. Remarkable and even great theoretical achievements cited in this set of letters are simply not in the same league.

At Princeton University in 1946, I saw all the great theorists—you name them, they were there—completely at a loss about the infinities