Principle approach

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Longing for the Harmonies: Themes and Variations from Modern Physics. By Frank Wilczek and Betsy Devine. *Norton: 1988. Pp. 361. $19.95.*

SCIENCE'S great gift to human understanding of the material world can be epitomized in a single word — simplicity. When applied to descriptions of reality, simplicity conveys two interrelated meanings, economy of expression and economy of hypotheses, or laws. Experience has taught us that the most useful descriptions of nature can be formulated precisely and elegantly. We do not believe that a separate agent lies behind each phenomenon in the physical Universe, but have come to idealize the notion, which we can trace to William of Ockham, that a few laws that apply in the same fashion at all times and in all places should be sufficient to describe reality.

How are we to arrive at such laws? A style of thought that has continually been rewarded is to take seriously great principles, to follow their consequences to the logical conclusion and not to sacrifice them lightly. By taking seriously Newton's theory of gravity, Adams and LeVerrier inferred the existence of the planet Neptune from anomalies in the orbit of Uranus. By taking seriously the law of conservation of energy, Pauli conjectured the neutrino from the energy spectrum of electrons emitted in radioactive beta-decay.

In such cases, the new invention is not offered as a replacement for existing law, but as a logical outcome that must be true, if existing law is still to hold. The operative question is not, "Can you disprove this?", but "How could it be otherwise?".

What John Archibald Wheeler has called the "radically conservative" strategy is the unifying theme of this elegant book by Frank Wilczek, one of the most imaginative and wide-ranging of theoretical physicists, and engineer–writer Betsy Devine. Wilczek and Devine characterize radical conservatism as "conservative in its reluctance to introduce new assumptions. . . . Creative tension and power is added to it by a radical approach to the few assumptions that are adopted. These assumptions must be formulated precisely and pushed as hard as possible. Their consequences must be fully drawn; they must be applied to as many situations as possible in the natural world and to the oddest and extremest conditions we can set up in the laboratory".

Uniformity, a second pervasive theme, is introduced by showing that we and the stars are made of the same stuff, so we can learn in terrestrial laboratories the physical laws that govern the structure of the Universe, and we can apply here on Earth what we learn by studying the heavens. The puzzles of uniformity — why are all the fundamental building blocks the same throughout the Universe, and why is the Universe so uniform — are raised, and our current understanding explained.

In between, many important topics in the quest to understand the microscopic structure of matter and the large-scale structure of the Universe are introduced in turn. A discussion of the cosmic distance ladder leads to Hubble's discovery of the expansion of the Universe, and to the Big Bang. The wave–particle duality of quantum mechanics is developed with care, and the combination of relativity and quantum mechanics is shown to lead ineluctably to antimatter and virtual particles. The elements of what has come to be called the Standard Model of Elementary Particle Physics are developed in a logical and insightful manner. Pauli's principle, which accounted for the periodic table of the elements, and the notion of quarks lead by the radically conservative path to the necessity of a charge of the strong interaction called 'colour', from which it is irresistible to formulate the promising and comprehensive theory of the strong interactions, quantum chromodynamics. The notion of hidden symmetries is the basis for our current understanding of the weak interaction, and prompts us to imagine more perfect worlds, in which the full symmetry might be manifest. There the dream of a unified theory of the fundamental interactions would be reality.

Throughout the book, the science is sound and well chosen, the writing is graceful and the analogies are apt. I particularly enjoyed the autobiographical interlude, "How Asymptotic Freedom Discovered Me", for its description of the historical setting in which Wilczek and his mentor David Gross undertook the calculations that led them to discover (at the same time as David Politzer) that in gauge theories the effective coupling strength could decrease at short distances or high energies. It was great theoretical sport in the early 1970s to show that observations of deeply inelastic scattering of electrons from protons could not be reconciled with relativistic quantum field theory. Some players took pleasure in proving that field theory itself must be wrong; others derived amusement from showing that the model of the proton as a collection of quasi-free quarks ('partons'), enunciated by Richard Feynman and others to interpret the experiments, was inconsistent with quantum field theory and therefore had to be incorrect. As Wilczek relates it (and it coincides with my recollection as a spectator), the goal of the Gross–Wilczek work was to drive the last nail into the field-theory coffin by studying gauge theories, the class of field theories left for last because of the technical difficulty of the calculations. Their plans were dashed when they found that in gauge theories quarks behaved as if they were free of the strong interaction, at asymptotically high energies. They had not found what they were looking for, but something more interesting than they might have dared to dream. Wilczek's account is a refreshing counter-example to the belief that scientists always know where they are going.

Longing for the Harmonies is a fine account for the general reader of how science is done, and of the interplay between theory and experiment that is crucial to progress. It gives an up-to-date picture of our struggle to understand the Universe as a whole, its basic constituents and the interactions among them. It is not, however, a complete picture of the physical world. The same themes of uniformity and the radically conservative strategy apply, with equal success, to what lies in between the very large and the very small, and to phenomena associated with collections of simple systems. Wilczek and Devine correctly note that "It is no small part of the charm of physics that, after more than three hundred years of astonishing progress, there remain absolutely major and fundamental problems". It is no less a part of the appeal of our science that it has a great and growing unity. Dare we hope for a sequel in which the phenomena that operate on the scale of everyday experience, of condensed matter and complex systems, are linked with those of the cosmos and the microworld? □

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