BOOK REVIEWS

A View of the Particle World

Conceptual Foundations of Modern Particle Physics. ROBERT E. MARSHAK. World Scientific, River Edge, NJ, 1993. xxviii, 673 pp., illus. $86 or £61; paper, $46 or £32.

Robert E. Marshak was a distinguished theoretical physicist who grew up with the field of particle physics. The author, with Hans Bethe, of the two-meson hypothesis that disentangled Yukawa's nuclear-force carrier, the pi meson, from the unexpected muon and, with E. C. G. Sudarshan, of the V − A hypothesis that brought Fermi's theory of beta decay into accord with the evidence for parity violation, Marshak was for a half-century one of the great enthusiasts of particle physics. He was also an ardent internationalist, animator of the "Rochester Conferences" that grew into the biennial International Conference on High Energy Physics.

Marshak saw particle physics emerge from nuclear physics, pass through several periods of splendid confusion, and grow to maturity, nourished by a host of experimental results from cosmic rays and accelerators. *Conceptual Foundations of Modern Particle Physics*, which was completed just before his death at the end of 1992, is his intellectual summation, his analysis of the ideas that have brought the theoretical understanding of fundamental processes to its present highly successful, yet incomplete and tantalizing, state. It is the record of a life in particle physics, less a textbook than a statement of how the author thought, what problems captured his fancy, and what issues preoccupied him.

Conceptual Foundations opens with a rapid-fire survey of the intellectual history of particle physics, organized into three 15-year eras. During the "start-up period," 1945–1960, the idea of gauge invariance took root in the formulation of quantum electrodynamics and non-Abelian gauge theories. Spontaneous symmetry-breaking became a familiar notion, while the phenomenology of pion physics, strange particles, and the universality of weak interactions led to a growing appreciation of the power of symmetry arguments. In the "heroic period" of 1960–1975, quarks and leptons were recognized as the basic constituents of matter and gauge theories emerged as the correct descriptions of the strong, weak, and electromagnetic interactions. Marshak calls the era 1975–1990 a "period of consolidation and speculation" in which the electroweak theory and quantum chromodynamics survived increasingly rigorous experimental tests, the theoretical underpinnings of gauge theories were buttressed, and audacious speculations opened the possibility of a more comprehensive understanding. Such speculations—on the unification of the strong, weak, and electromagnetic interactions, on the origin of the three generations of quarks and leptons, and on the application of topological conservation laws—were the stuff of Marshak's late work and take up the last third of the book.

In the six chapters that make up the heart of *Conceptual Foundations*, Marshak reviews the key ideas that come together to define modern particle physics. He lays great stress on the gauge principle—the idea that symmetries determine interactions—and on the role of anomalies, quantum fluctuations that do not respect the symmetries of a classical field theory, in fixing the structure of the standard model. More idiosyncratic is the focus on issues that shaped his own thinking at crucial moments: chirality invariance, the Landau singularity in the running coupling constant of quantum electrodynamics, and no-go theorems that show the impossibility of combining Poincaré invariance with global internal symmetries.

Conceptual Foundations will be most useful to the reader who already knows the ideas treated. It is more an exegesis for knowledgeable colleagues than a systematic development for students. There are no exercises to fix new concepts in a reader's mind. Few will want to read this book from cover to cover, but it would be interesting to pull it from the library shelf, to see what Marshak has to say about a particular subject. There are some nice passages, including an unusually thorough and thoughtful treatment of the analogy between the Ginzburg-Landau picture of the superconducting phase transition and the Higgs mechanism for spontaneous breaking of electroweak symmetry.

A better subject index, as well as an author index, would have made dipping into *Conceptual Foundations* more rewarding. One of Marshak's last influential pieces of research was his exploration of neutron-antineutron oscillations in $SO(10)$ unified theories. Unfortunately, the first index entry leads, in error, to a section on *neutrino* oscillations. The reader who perseveres to the final entry will be rewarded by a clear, orderly, but swift presentation of the conditions that can give rise to neutron oscillations. In the matter of indexes and misprints, Marshak could have been better served by his publisher. A thorough copyediting would have made the book much more appealing to read and use.

The strength of *Conceptual Foundations* is that Marshak is alive on the page, a man of many words, fully engaged, always with a definite point of view. His joy in understanding—in striving to understand—is a constant companion.

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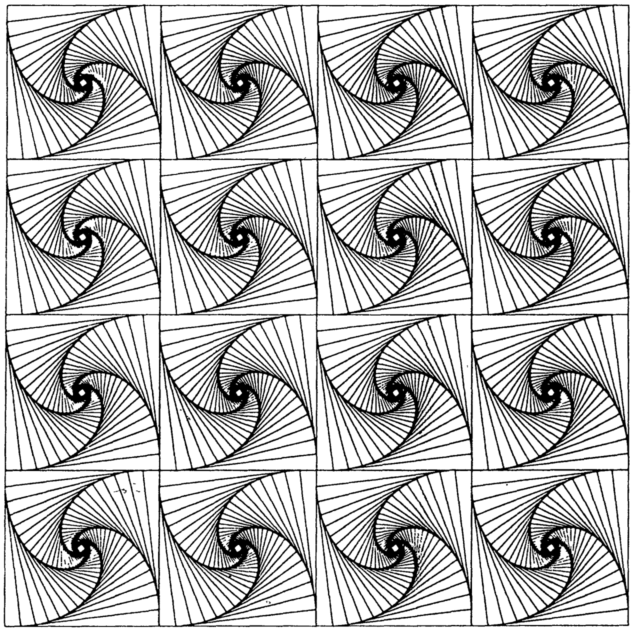
~2.71828

e. The Story of a Number. ELI MAOR. Princeton University Press, Princeton, NJ, 1994. xiv, 214 pp. $24.95 or £19.95.

Most numbers are "transcendental." Very informally this means that they lack a simple definition. Most numbers with names are not of this variety so 2, $\sqrt{3}$, and $\frac{7}{5}$ are not such numbers. Indeed, most people only know the names of one or two transcendentals: the best known is π, the second is e. So many numbers are transcendental that if all the numbers were put in a barrel, it is as good as a certainty that the first number pulled out would be so. (In such a lottery always bet on the transcendentals.) So why do we give names to so few? In part because there are not enough names to go around, and in part because most of these numbers arise for no particularly natural reason.

Why do π and e merit special treatment? The answer lies in the ubiquitous ways in which they arise in mathematics. It is very hard to conceive of the inhabitants of a distant planet acquiring any mathematical sophistication without encountering (discovering) π and e. While π is easier to define (as the circumference of a circle of diameter 1) e is in many respects more fundamental. It is impossible to imagine the development of calculus without the invention of e and its big brother the exponential function $exp(x)$. We describe our physical world by differential equations, as we have since the time of Newton, and the most basic differential equation of all ($f' = f$) is the one satisfied by $exp(x)$.

Almost as important as the discovery of calculus was the invention of logarithms in the early 17th century. And logarithms, also, lead inexorably to e. As Maor points out, "Rarely in the history of science has an abstract idea been received more enthusiastically by the entire scientific community than the invention of logarithms." A table of logarithms was, in the 17th century, as indispensable to a scientist as a microcomputer is now. The slide rule, a device based directly on logarithms and invented almost immediately after their discovery, has really only been made obsolete in the last 20 years with the advent of portable electronic calculators.



A decorative design based on the Four Bug Problem. "Imagine four bugs positioned at the corners of a rectangle. At the sound of a signal, each bug starts to move toward its neighbor. What paths will they follow, and where will they meet? The paths turn out to be logarithmic spirals that converge at the center." [From *e*]

Pi has, on some level, permeated the public consciousness. Aristophanes mocks circle-squarers in *The Birds*. A variety of books have been written on π, and considerable time, profitable and unprofitable, has been spent computing its digits. Pi has even been the subject of legislation. There is a bill still tabled in Indiana, dating from late last century, attempting to regulate its value. It has also been the subject of some beautiful and serious mathematical scrutiny. Certainly one of the landmarks of 19th-century mathematics was Lindemann's proof of the transcendence of π in 1882, a proof that showed that circle squaring is impossible, as everyone, except cranks, had "known" for centuries. Hermite's proof of the transcendence of e ten years prior to this, while less celebrated, was probably more seminal. To the best of my knowledge no one has ever tried to legislate the value of e, and far fewer people have computed its digits than have done so for π (although a billion digits of e have been calculated recently, mostly because they can be). There have been a number of biographies of π, but this is probably the first major biography of e.

The idea behind this book is good one: to weave the historical development of the ideas of calculus around the life story of e. It is like the voyages of Columbus as told by the first mate. While this makes the point of view somewhat idiosyncratic, it also allows for considerable amusing discursion and renders the whole story much less dry than is usual.

Calculus is one of the truly remarkable inventions of humanity. It has shaped our lives in more ways than most of us recognize (there is precious little technology without calculus), and Maor is right to put e in the context of calculus, but even without calculus e has a pretty interesting life story. Nor is the story complete. Some very basic questions about e are completely intractable by current methods. We don't even know, for example, if $e + \pi$ is irrational, and we know virtually nothing about the digits of e.

Maor has succeeded in writing a short, readable mathematical story. He has interspersed a variety of anecdotes, excursions, and essays to lighten the flow; included, for example, is an imagined dialogue between Bach and Bernoulli on the mathematics of the "equal-tempered" scale. The heaviest mathematics is wisely relegated to appendixes.

This book is not written for either the professional mathematician or the historian of mathematics, and both groups will inevitably take umbrage at the treatment of some of the issues. This fate awaits all popularizations of mathematics, no matter how good, and partly accounts for why there are so few serious attempts at it. The necessary compromises between rigor and readability are daunting, as is talking about mathematics without talking only in mathematics (which is Greek to most—except far more people actually speak Greek).

This is, however, a good book to read in conjunction with an introductory calculus course. Since up to a million people a year study calculus across North America, this alone offers a substantial audience. It puts most of the ideas of such a course in a far richer and more human context than is standard. This is Maor's intended goal and also his primary success.

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Mammalian Evolution

Morphological Change in Quaternary Mammals of North America. ROBERT A. MARTIN and ANTHONY D. BARNOSKY, Eds. Cambridge University Press, New York, 1993. x, 415 pp., illus. \$74.95 or £45.

The Quaternary Period was a time of extensive environmental fluctuations. Terrestrial vertebrate fossil assemblages of this period tend to be larger, have a broader geographic coverage, and can be dated more precisely than older fossils. These factors make the Quaternary an ideal laboratory for evolutionary studies based on the fossil record. This collection of 16 such studies covers a wide range of taxa including moose and mammoths (Lister), edentates (Hulbert and Morgan), deer (Purdue and Reitz), jaguars (Seymour), prairie dogs (Goodwin), prairie voles (Barnosky), and woodrats (Zakrzewski).

Rates of evolution figure prominently in most of these papers. The controversial issue of the calculation of rates and their relationships to the intervals over which they are calculated is reviewed by Gingerich. In one of the more innovative contributions in the book, he expands on his earlier observation that evolutionary rates vary inversely with the period of time over which they are calculated. He devises a new approach using rates of evolution to produce two rates, an "intrinsic rate" over one generation and a "net rate," an average calculated over more than one generation. This technique allows one to discriminate among process change, randomness, and stasis.

Another controversial topic, that of stasis, or the absence of significant change in a character through time, and its recognition in the fossil record is dealt with in two papers. Anderson reviews statistical meth-