

George Ellery Hale began the modern reflecting-telescope revolution. Hale desired "more light" to explore solar phenomena in other stars. He wrote: "Thousands of stars, in the same stage of evolution as the Sun, doubtless exhibit similar phenomena, which are hidden from us by distance. . . . In spite of the necessity, because of their feeble brightness, of basing our conclusions on spectra a few inches long, representing the combined light from all parts of the stellar disks, material progress could be made in this way." (*Ten Years' Work at a Mountaintop Observatory*, Carnegie Institution of Washington, 1915.)

Roger Tayler's *The Sun as a Star*, a modern précis of Hale's idea, is an excellent introduction to the Sun and its local environment. Tayler (who died in January 1997) admirably reviews, at the vector calculus level, basic plasma physics and magnetohydrodynamics. The book is the companion and sequel to Tayler's earlier *The Stars: Their Structure and Evolution* (2nd ed., Cambridge University Press, 1994), but it stands on its own. The book flows well, with summaries of each chapter and detailed coverage of collateral topics in appendices.

Tayler's solar physics has two facets: First is that of the Sun's slowly varying radiative energy and related topics on the interior. Here the most important research problem is the observed deficit of neutrinos. Tayler deftly summarizes the experimental results and theoretical explanations of the neutrino deficit. His conclusion is that neutrino physics needs revision.

Some of Tayler's information may quickly be outdated by rapid movement in the field. For example, new details on the solar interior are flowing from such helioseismology experiments as GONG (Global Oscillation Network Group) and SOHO (Solar and Heliospheric Observatory) which are separating the p-modes of the five-minute solar oscillations excited by acoustic energy from subsurface convection. Nonetheless, Tayler's book is needed and should remain a useful introduction to the subject for some years.

The second facet of Tayler's approach is the Sun's activity, its spatial and temporal variability. One of his themes is to explore the relation between surface activity and magnetic fields, including radiation and particle emissions. Another is the complex interaction of the Sun's magnetic field and particle emissions with the Earth's space environment.

A third theme comes from the book's title itself, and I found it less thorough than it might have been. Tayler does cover other stars that by virtue of rapid

rotation (the result of stellar youth or tidal forces in close binaries, for instance) have extreme levels of surface magnetism. "Starspots" on the star types BY Draconis or RS Canum Venaticorum can cover 10% or so of the stellar surface, compared to the Sun's spot coverage of generally less than 1%. But Tayler omits much work done in the last decade on the activity of Sun-like stars. For example, Wes Lockwood and Rich Radick at Lowell and Sacramento Peak Observatories respectively pioneered high-precision, visible-band photometry showing magnetic features on other stars comparable to the Sun's. Greg Henry (Tennessee State University) and his colleagues run a revolutionary program using automated telescopes that get nightly photometric precision of 100 to 200 millionths of a magnitude. Henry's group has seen on other Sun-like stars the counterpart of the Sun's 0.1% amplitude irradiance change, over the course of its 11-year cycle. Such advances should have been included in Tayler's book.

Tayler places studies of the Sun and its influence on the interplanetary medium at "the centre of modern astronomy." The reason is the proximity and richness of the Sun as a laboratory of plasma physics and magnetism. He marvels at the Sun's complexity compared to, say, galactic nuclei. But Tayler cautions that objects like galactic nuclei may seem deceptively simple, because the spatial and temporal details are lost in their great distance and feeble brightness.

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Crystal Fire: The Birth of the Information Age

Michael Riordan
and Lillian Hoddeson
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Last year marked the 50th anniversary of the discovery at Bell Laboratories of transistor action in germanium. *Crystal Fire* recounts the history of this epoch-making discovery and subsequent events that led to the dawning of the information age. Michael Riordan and Lillian Hoddeson provide a gripping account not only of the transistor discovery but also of the birth of solid-state physics, with its intimate relationships to quantum mechanics

and to the world of technology. The book provides insightful analysis of the coupling of research and application as well as the human relationships and the inner workings of one of the world's greatest industrial laboratories.

The early chapters of the book give an eminently readable account of the quantum mechanical foundations of solid-state physics. The authors also trace the more detailed and pragmatic efforts at AT&T to develop vacuum-tube amplifiers for long-distance communication. These efforts were successful enough to convince AT&T brass that hiring PhD physicists to work on problems relating to communications technology was good business! By the mid-1930s, with Bell Labs' research director Mervin Kelly convinced that the behavior of electrons in solid-state materials and an understanding of modern quantum physics might be important in replacing bulky vacuum tubes, Kelly hired William Shockley, who had recently obtained his PhD at MIT.

The implementation of Kelly's vision of replacing mechanical switches with electronic ones to connect telephone subscribers in the Bell system was interrupted by World War II; with MIT's Radiation Laboratory, Bell Labs became a major player in microwave radar development during the war. Major efforts in purification of silicon and germanium led to the development of high-quality crystal rectifiers and microwave radar.

By the time the war ended, Kelly was firmly convinced that AT&T needed to be at the forefront of solid-state physics research, and he asked Shockley to head the work. To bolster the effort, Shockley suggested to Kelly that a theorist of outstanding credentials needed to be added. And so John Bardeen, who had been working during the war at the Naval Ordnance Lab, and with whom Shockley had interacted during his stay at MIT, was recruited by Kelly and offered a position in the solid-state physics group. Walter Brattain, an experimentalist who had joined Bell Labs many years earlier and who worked under Clinton Davisson, was also part of the group, as were physical chemist Robert Gibney and electronics expert Bert Moore.

Riordan and Hoddeson give an insightful and thorough treatment of the history surrounding the 1947 discovery of transistor action in germanium using point contacts and in p-n junctions three years later. They also provide a fascinating account of the years immediately following the transistor discovery, a time when the Korean War was raging and a looming antitrust action against AT&T provided conflicting scenarios for the dissemination of critical materials

technologies for both military and commercial communication purposes.

At a transistor symposium in Murray Hill, New Jersey, in 1952, Bell Labs disclosed key materials breakthroughs that had been made in the fabrication of junction transistors. At about the same time, the US Air Force drafted Bell Labs' expertise to develop a network of early-warning radar stations. The cold-war arms race with the Soviet Union had begun, and the fledgling semiconductor industry was destined to be backed by the US government at a pace that was further accelerated by the launch of Sputnik and the subsequent space race with the Soviet Union.

Riordan and Hoddeson offer much insight into the personal workings of great scientists and inventors. Even as major breakthroughs were occurring in the 1950s, they recount, Bardeen, excluded from subsequent work by the increasingly touchy and difficult Shockley, had begun work on superconductivity, ultimately leaving to join Frederick Seitz at the University of Illinois in the summer of 1951. Further, Shockley himself became increasingly disenchanted with Bell Labs when he was passed over and Jim Fisk appointed as director of research. Shockley teamed up with fellow Caltech graduate Arnold Beckman to form Shockley Semiconductor Laboratory, in Palo Alto, California, in 1956. Shockley Semiconductor soon recruited such outstanding scientists as Gordon Moore and Robert Noyce. But even though Shockley thus proved himself again to be a prodigious recruiter of talent, he was unable to manage the creative talent he had brought together with Beckman's backing. A group of eight, led by Moore and Noyce, resigned in September 1957 to form their own company, backed by Fairchild Camera and Instruments.

Silicon Valley owes a significant portion of its genesis to Shockley Semiconductor, and Shockley has been referred to as the "Moses of Silicon Valley" by his longtime friend Seitz. But Shockley himself profited little from his efforts.

Crystal Fire provides a remarkable look into these highlights—and much more—of the story not only of one of the greatest inventions of the 20th century but of the birth of the information age. It is a must-read for every solid-state physicist, device engineer and materials scientist, as well as for those interested in the intimate coupling of fundamental science with application.

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The Truth of Science: Physical Theories and Reality

Roger G. Newton
Harvard U. P., Cambridge, Mass.,
1997. 260 pp. \$27.00 hc
ISBN 0-674-91092-3

Roger G. Newton is a theoretical physicist already well known for his highly technical, foundational work in quantum mechanical scattering theory. In *The Truth of Science*, he gives us an exemplary nontechnical but thoughtful and clear description of science and its relation to truth. It is intended for an educated general reader and requires no familiarity with the mathematical aspects of physics. This book should prove to be of interest to a wide audience, since the question of the truth and objectivity of science has recently been brought to the fore, even among scientists, by the so-called Science Wars.

This latter expression refers to an extensive and ongoing exchange of volleys between the "hard-science" and the "sociology-of-science" camps. These represent opposite ends of a spectrum: Members of the first group take the laws and theories of science to represent an objective and accurate picture of the world, while extremists in the second see the very form and content of science as a purely social construct. Recently, a minor skirmish even took place in the pages of *PHYSICS TODAY* (July 1996, page 11 and January 1997, page 11). Among the combatants in the larger campaign have been distinguished scientists (some Nobel laureates), historians and philosophers of science, and social constructivists. Unfortunately, the discussants have too often talked past each other, without taking proper cognizance of arguably valid points made by the other side. While neither extreme is wholly defensible, the real problem, it seems to me, is just where one should come down between these extremes. There certainly is an important issue here and the stakes are high: whether (1) science gives us reliable knowledge about the way the world actually is, or (2) simply offers us a plausible story about the way the world might be.

The Truth of Science opens with a preface and an introduction that address this question and, not unexpectedly, come down largely on side (1). Much of the rest of the book is presented as further brief for the scientists. It is a comprehensible, certainly technically correct and generally evenhanded account of science—one almost universally subscribed to by the scientific community. Science comes across

as an objective enterprise that discovers reliable laws and theories about nature, these converging toward truth. Are matters really so straightforward, though? While there are aspects of scientific practice (for example, the ever-increasing scope, accuracy and predictive power of our successful scientific theories) that support position (1) above, there are also other (external) factors (for example, the influence that social and even psychological elements have had on the structure of scientific theories) that lend credence to (2). This difference in outlook is what is at the heart of the Science Wars. While it is quite reasonable to position oneself between the extremes, there seems to be no objective set of criteria that will both command essentially universal assent and determine uniquely the proper location on the spectrum.

Roger Newton constructs an appealing case for a very positive and optimistic view of science on the basis of an often literate and nuanced examination of the history and content of scientific theories and of associated philosophical questions. His book is a useful addition to the general literature on the nature and goals of the scientific enterprise. He does make some conciliatory gestures toward the influence of external factors on science, but certainly not enough to bring into his fold those partial to a less sanguine view of science. Although I am inclined to give somewhat more weight to external factors than does Newton, I must say that he has made a good case for his view of science—perhaps about as good as one is going to find. One can only hope that continued, civil dialogue of the kind in this book will contribute to an accurate, widely accepted representation of science and of the type of knowledge it gives us, and, in the process, to an accommodation between polarizing views.

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Flash of the Cathode Rays: A History of J. J. Thomson's Electron

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Per F. Dahl's *Flash of the Cathode Rays: A History of J. J. Thomson's Electron* is perhaps the first book-length monograph on the history of the electron to appear since David Anderson's *Discovery of the Electron* in 1964 (Princeton U. P., Van Nostrand). Dahl's book is