were able to construct a computer that was very reliable. And what of the fact that the Institute for Advanced Study itself did not enjoy having the computer on its campus and tolerated it only because having it was seen as the only way that von Neumann would agree to reside there? This case hardly represents a harmonious and exemplary transfer of knowledge from the academic to the commercial world.

Still, this book has much to recommend it—the author has a sense for what is important about von Neumann's life and work, and he convinces us that we, too, should concern ourselves with it. And he does that with a clear and forceful style of writing that few popular science books have. No doubt as historians take a more dispassionate look at the Cold War and as we begin to understand better the impact of the electronic digital computer in our lives, "Johnny" will get the attention and credit he deserves.

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Redefinitions in Physics

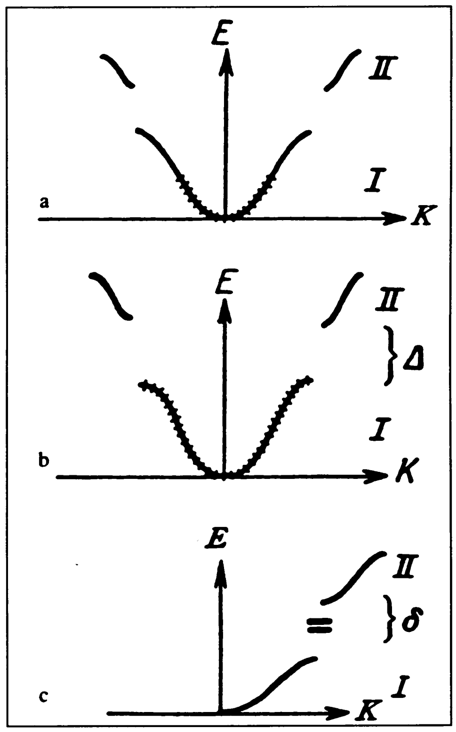
Out of the Crystal Maze. Chapters from the History of Solid-State Physics. LILLIAN HODDESON, ERNEST BRAUN, JÜRGEN TEICHMANN, and SPENCER WEART, Eds. Oxford University Press, New York, 1992. xxiv, 697 pp., illus. $75.

Now familiar to every physicist, the term "solid state physics"—probably coined after its German equivalent, *Festkörperphysik*, used occasionally since the 1930s—was not in use before the 1940s, and for some physicists the term even then sounded "kind of funny," as one of them put it in 1944. The many properties of solid matter now regarded as part of that specialty—crystal structures, magnetism, electrical conductivity of metals, mechanical properties of solids—were originally studied by chemists, engineers, and physicists having little if any contact with each other. As the authors of the first chapter of *Out of the Crystal Maze* note, the field was a mosaic "in which each tile seems scarcely related to the next." The conceptual unification of these phenomena and their integration into the discipline of physics would come only after the emergence of new experimental techniques and methods—the most important being low temperature and x-ray crystallography—and the development of quantum mechanics (as detailed in the book's second chapter). It would also be greatly stimulated by the applications developed during the Second World War and pursued afterward in many industrial laboratories hiring research physicists.

The emergence of solid state physics as a specialty can be understood only by taking into account both intellectual and social developments. On the one hand, publications by Heisenberg, Pauli, and Bloch applying the new quantum mechanics to electrons in metals showed that it was now possible to solve the problems raised by the classical theory of Drude and Lorentz and its semiclassical version developed by Sommerfeld, thus opening the possibility of making detailed calculations of the different properties of solids. On the other hand, the formation of the specialty was also strongly fashioned by the demographic growth of the discipline of physics starting in the 1930s and accelerating after the war. Whereas physicists like Pauli and Heisenberg were interested in the solid state only as a test case for quantum theory, the younger generation was much less mobile and settled for life to study a particular subset of physical phenomena. This specialization led to a redefinition of their social identity as they came to perceive themselves more and more as "solid-state physicists" rather than simply as physicists moving from subject to subject like their predecessors. This process was also greatly influenced by the fact that more and more of them were working in industry rather than in academe. In the United States, for example, the difference in outlook between industrial and academic physicists brought about, after years of discussion and in spite of fears of "balkanization" of the society, the creation within the American Physical Society of a solid state division as a means of discouraging industrial physicists from leaving the society to create their own organization.

The history of the scientific efforts that went to make up the field is detailed in *Out of the Crystal Maze* in separate, variously authored chapters devoted to band theory, point defects and color centers, mechanical properties of solids, magnetic materials, semiconductors, and superconductivity and critical phenomena. These chapters can be read independently of each other, and I suspect that scientist readers will go directly to the chapters most closely related to their own research interests, for the book is "written chiefly for people with some education in physics" and many of the chapters are quite specialized and cannot really be understood without a fair amount of technical knowledge. Overall, the account is written from the point of view of the theoretician. The evolution of the theoretical understanding of phenomena is at the center of most of the chapters, and experimental and technological advances receive much less attention.

Notwithstanding the common factors that went into the evolution of the field, I am not convinced by the treatment of the subject in *Out of the Crystal Maze* that by the 1950s these physicists were part of a "solid community," as is suggested by the title of the chapter by Spencer Weart that concludes the volume. The paucity of interconnections among the accounts in the book would suggest that the distance separating some of these subspecialties is large, comparable perhaps to that separating optics from nuclear physics. The authors of the chapter on magnetism even talk of a "magnetics community," and the development of big magnets led some scientists such as Aimé Cotton to become interested more in the instruments themselves than in using them to study solids. If for some time



"Alan Wilson's picture of electron energy *E* versus wave number *K*, with a band gap of width Δ. (a) A metal, with all the filled electron states well below the gap; (b) an insulator, with filled states reaching up to the gap, which blocks the electron motion; (c) (after Bloch) a semiconductor with impurity states in the gap. (From F. Bloch, 'Wellenmechanische Diskussion der Leitungs und Photoeffekte,' *Phys. Zs.* 32 [1931]: 883, 886)" [From *Out of the Crystal Maze*] after the war the term "solid state" helped define a set of problems in physics, it did not for long correspond to a social community in which members had strong ties to each other, except in periods when they had to struggle against other interest groups in physics.

The book as such is an example of what might be called "big history of science," stemming as it does from an international collaboration and guided by advisory committees that "consisted largely of senior physicists but also included historians and sociologists of science." Readers are assured of its scientific credentials by the *imprimatur* given in a short foreword by E. Mollwo and two founding fathers of the field, Nevill Mott and Frederick Seitz.

As for the overall emphasis of the treatment, "the choice or elimination of the various topics was," according to the editors, "endorsed by our scientific advisors." Though choices are always to some extent arbitrary, I think the way they have been made is far from satisfying from the point of view of the professional historian of science. Whereas recent historiographical concerns have centered on instruments or on industrial or military influence on the direction of research, the main criteria used to select topics for inclusion here were "fundamental scientific significance" and "role played in technological innovations." The role of the military in some of these developments—which cannot have been negligible—is given short shrift. Given the intended audience for the book one could hardly have expected a truly social history of the specialty, and fortunately for the social historian research schools and the institutional structure of the field are discussed in some chapters, particularly Weart's. But in truth this book, like earlier collective works in the history of particle physics, fills for the scientific community a social function that was well summarized by Leon Lederman in his preface to one of those works, where he wrote that the immediate benefit of that volume would be for those working in the field, for it would "help them raise their consciousness about the fact that the field in which they work in has a culture and a history, to which they contribute in their everyday work."

The editors are conscious of the limitations of their work and express the hope that its "very inadequacies . . . will work as a stimulus to further research into the history of this grand field of knowledge." In order to facilitate such research the Center for the History of Physics of the American Institute of Physics has published a *Guide to Sources for History of Solid State Physics*, compiled by Joan Warnow-Blewett and Jürgen Teichmann. Let us hope that historians of science will use it—alongside the present book—but this time to frame their questions in the terms of their own discipline rather than according to the preoccupations of the scientists, which are perfectly legitimate but nonetheless distinct from those of historians.

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Technological Winners

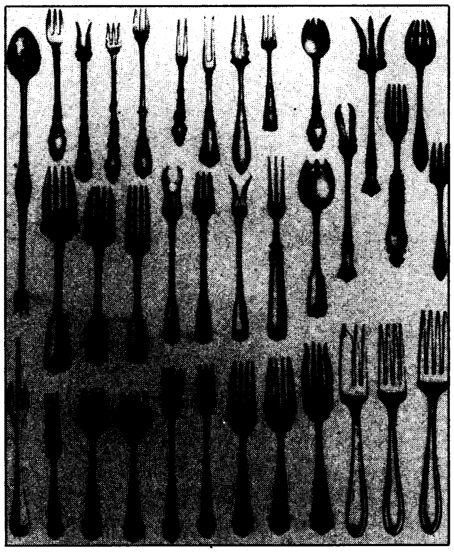
The Evolution of Useful Things. HENRY PETROSKI. Knopf, New York, 1992. xii, 289 pp., illus. $24.

In his *Just-So Stories*, Rudyard Kipling tells tall tales about what might be called, loosely speaking, the "evolution" of animals. How did the camel get its hump? How did the leopard get its spots? Henry Petroski's *The Evolution of Useful Things* is a collection of "just so" stories about technology. It's a series of historical vignettes intended to explain, as the dust jacket of the book has it, "how everyday artifacts—from forks and pins to paper clips and zippers—came to be as they are."

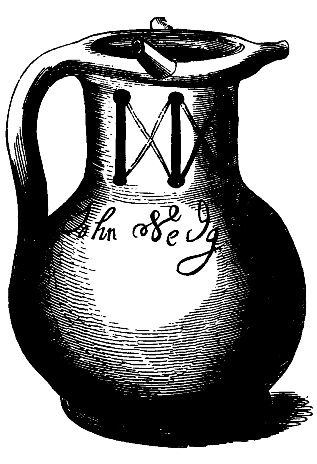
Petroski's theory is a simple one. He reduces the development of all technologies to a simple rule: "form follows failure." By this he means that new technologies replace old because the old ones fail their users in some way. The fork evolved because the knife wouldn't hold a piece of meat for cutting—and then evolved into a baroque variety of forks because a simple standard fork failed at specialized tasks, like picking up fish or oysters. The motorcycle comes about because the bicycle failed to go under its own power—and then evolved further as inventors searched for the least undesirable arrangement of components. The zipper emerges because buttons didn't do a good job of fastening shoes.

These are fascinating stories, but they remain only stories. Petroski's attempt to build a theory of technological change from them fails. His rule of "form follows failure" is a tautology. It has no explanatory power, but merely suggests that we arrived at the current state of technology because the old way failed and the new way was "better." His evolutionary theory includes neither a mechanism to explain novelty nor a mechanism to explain selection. It looks back at each decision from the viewpoint of the "right" answer, rather than looking at the full context of the situation where the variation and selection occurred. It's a map that shows only those forks in the road we decided to take.

The problem stems from Petroski's sources and from his narrow focus on invention. Petroski's sources tend to be historical retrospectives by the technological "winners." So the story of the zipper is taken from a publication by Talon, Inc., the story of the Post-It note from an official 3M company history. These sources tend to play up the "how'd we ever live without it?" side of the story. Petroski's treatment of industrial design, told exclusively from the memoirs of designers, shows a similar prob-



Victorian flatware. "This collection of forks shows the variations available in several silver patterns. *Top row, left to right*: oyster fork-spoon, oyster forks (four styles), berry forks (four styles), terrapin, lettuce and ramekin fork. *Middle row*: large salad, small salad, child's, lobster, oyster, oyster-cocktail, fruit, terrapin, lobster, fish, and oyster-cocktail fork. *Bottom row*: mango, berry, ice-cream, terrapin, lobster, oyster, pastry, salad, fish, pie, dessert, and dinner fork." [From *The Evolution of Useful Things*]



"Earthenware 'puzzle jugs,' such as [this one] were produced by the Wedgwood family in the late seventeenth century. These ale jugs were deliberately designed to be confusing to use and served as a basis for wagering in alehouses. The drinker would bet he could down the ale without spilling any, but to do so he had to cover up the right combination of holes and tubes, lest the jug behave more like a dribble glass. Had a unique form existed, the practice of wagering might not have been so popular." [From *The Evolution of Useful Things*]