analysis of Western European alternatives, which typically involved fewer stations and considerably more government control. It would be bolstered, too, by comparison with the American motion-picture industry, which underwent a similar process of consolidation. Almost simultaneously with the networking of radio, a handful of film companies knit once-independent theaters into vast chains. Their products, emanating from a central source, became glossier and more cosmopolitan, and, using some of the same stars as radio, reflected reduced diversity in programming. The two dominant media of American popular culture are prime examples of the consolidation of national economic institutions in the 1920s and '30s.

Smulyan's welcome book reminds us that the instigation and durability of media hegemony owe as much to conscious corporate strategies as to technological inevitability. Enveloped in a world of commercialized media, we might, as she suggests, "consider whether the cost is too high" (p. 168).

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The Chemical Past

The Norton History of Chemistry. WILLIAM H. BROCK. Norton, New York, 1993. xxx, 744 pp., illus. $35; paper, $15.95. Published in the United Kingdom by HarperCollins as *The Fontana History of Chemistry*; paper, £8.99.

Ideas in Chemistry. A History of the Science. DAVID KNIGHT. Athlone, Cambridge, U.K., and Rutgers University Press, New Brunswick, NJ, 1992. vi, 213 pp. $47 or £38; paper, $18.

The History of Chemistry. JOHN HUDSON. Chapman and Hall, New York, 1992. x, 285 pp., illus. $59.95; paper, $24.95.

Histoire de la Chimie. BERNADETTE BENSAUDE-VINCENT and ISABELLE STENGERS. Éditions de la Découverte, Paris, 1993. 360 pp., illus. Paper, F180.

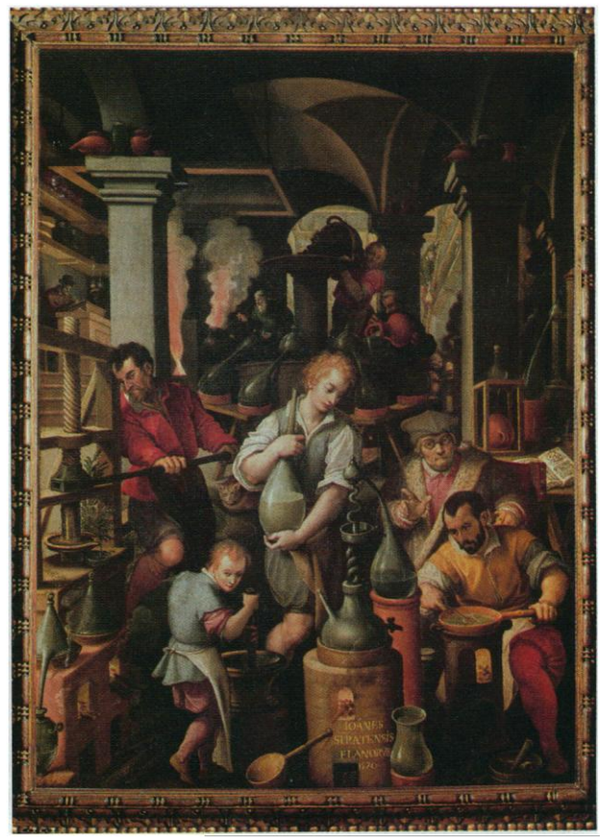
Throughout the 19th century and until the Second World War the history of chemistry was routinely part of the chemical curriculum in the United States and other countries. Many of the founders of the history of science as a discipline (for example, James Bryant Conant), as well as the most distinguished historians of chemistry (for example, James R. Partington and Aaron J. Ihde), have been chemists. Yet the history of chemistry began to disappear from the post-war, post-Sputnik university curriculum.

Some developments described by William Brock in *The Norton History of Chemistry* suggest at least two reasons. For example, Brock comments on the importance of Linus Pauling's 1947 undergraduate textbook *College Chemistry*. Since the early 19th century, chemistry textbooks largely had been organized in a sequence more or less corresponding to the historical development of the description and classification of elements, compounds, and their reactions, with some attention to apparatus and analytical methods. In contrast, Pauling's text opened with up-to-date theoretical principles based in quantum chemistry and thermodynamics. A result was an erosion of the traditional historical approach to chemistry.

In another context, Brock discusses how the curriculum reform that was an important focus of science education in the United States in the 1960s played itself out in chemistry. One approach, initiated by Laurence Strong and O. Theodor Benfey at Earlham College, became the basis for a high-school curriculum called the "Chemical Bond Approach" (CBA), emphasizing chemical concepts or systems, as distinct from chemical facts. A rival was the "CHEM Study" curriculum sponsored by the American Chemical Society, less theoretically demanding and more descriptive than CBA but also differing from CBA by removing the "dead wood" of the history of chemistry. The CHEM Study approach soon became widely extended, again eroding history in the chemical curriculum.

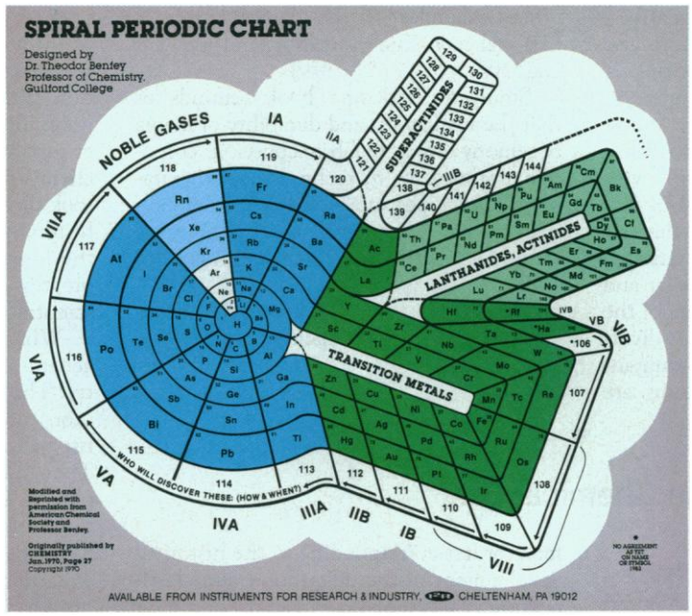
During the postwar period, professional philosophers and historians of science for their part demonstrated very little interest in chemistry apart from Lavoisier and the so-called Chemical Revolution of the 18th century. As David Knight notes in *Ideas in Chemistry*, giving us another insight into the decline of the history of chemistry, most philosophers of science took physics as their exemplar, as did most historians of science. They assumed that the history of physics best illuminates the progress of scientific ideas and the nature of scientific method.

Why now the appearance of these four general accounts of the history of chemistry? The texts and their authors are contributors to a renewal in the history of chemistry after a decline over several decades. Though Knight, as does Brock, gently disparages some (not all) influences on the history of science from the fashionable sociological approach emphasizing the "construction" of scientific knowledge, the approach is fully employed by Bernadette Bensaude-Vincent and Isabelle Stengers in their history of chemistry. In fact, it is precisely research—by no means all of it "constructionist" or sociological—emphasizing the history of scientific societies, science education, social networks, laboratories, language, rhetoric, gender, and the



"The Alchemist" by Johannes Stradanus (1523–1605); Palazzo Vecchio Studiolo, Florence. [From the dust jacket of *The Norton History of Chemistry*; Scala/Art Resource]

embedding of science in national cultures and national technologies that has helped revive studies in the history of chemistry. Brock and Knight have contributed elsewhere to this history, and some of these approaches are represented in essays in recent volumes like *Chemical Sciences in the Modern World* (University of Pennsylvania Press, 1993), edited by Seymour H. Mauskopf; *Research Schools: Historical Reappraisals* (University of Chicago Press for the History of Science Society, 1993), edited by Gerald L. Geison and Frederic L. Holmes; and *Die Allianz von Wissenschaft und Industrie: August Wilhelm Hofmann (1818–1892)* (VCH, 1992), edited by Christoph Meinel and Hartmut Scholz.



A spiral periodic chart designed by O. T. Benfey in 1970. [From *The Norton History of Chemistry*]

The revival of history of chemistry results, too, from concern among some chemists that their history should be better understood and that popular attitudes about the nature of chemical ideas and practice should be better informed. One consequence has been the establishment in the United States of the Chemical Heritage Foundation. Another has been the writing of essays and books by noted chemists, sometimes in collaboration, such as Roald Hoffmann in the United States and Pierre Laszlo in France.

Of the four histories under review, three were written by British authors, one by a French author and a Belgian author. As suggested above, the British authors, true to the tradition of British empiricism, present less sociologically and theoretically structured histories than their colleagues from across the Channel.

Hudson's history is written by a chemistry instructor for chemistry students. Its format is that of a school textbook, with boxed biographical sketches of major chemists, lots of illustrations and diagrams, an appendix listing Nobel Prize winners up to 1991, and separate name and subject indexes.

The prose is clear, and in many respects the book is modeled on Aaron Ihde's *Development of Modern Chemistry* (1964). Hudson's history is primarily a history of chemical ideas and theories, including some that have been modified or discarded, and it concludes with chapters on methods of analytic chemistry and society. The last chapter not only treats the organization of chemical societies but gives a brief history of chemical industries, in about the same order as treated in two of the other volumes: alkalis, nitrogen, synthetic dyes, drugs, and polymers. Hudson concludes with a discussion of the benefits and hazards of the chemical age, not unlike Ihde's conclusion in 1964.

Like the others, Knight's history is organized primarily on chronological lines, although he uses as chapter themes the successive rubrics "occult," "mechanical," "independent," "fundamental," "revolutionary or inductive?," "experimental," "useful," "deductive," "descriptive and classifying," "teachable," "reduced," and "serviceable." It is not always apparent that the title given to one chapter might not have served for another. There are many wonderful insights and vignettes in this history, but there is a troubling and over- arching theme, which becomes very explicit in the chapters called "A reduced science" and "A service science," to which I shall return.

The histories by Brock and by Bensaude-Vincent and Stengers are written to satisfy not only the chemistry student or teacher and the general reader interested in scientific ideas but also the advanced student or scholar who knows, or wants to know, a good deal about recent interpretations in the history of chemistry and the history of science more broadly.

Brock's volume (one of the first in a projected Fontana/Norton series of histories of scientific fields) is a superb and distinguished successor and complement to earlier works by Partington and Ihde. Chemical investigations and chemical theories are clearly described, skillful biographical studies of many major figures are given, and a great deal of groundbreaking scholarship has been addressed. This includes recent studies by William Newman on medieval alchemy, Alan Rocke on the "Quiet Revolution" in structural chemistry, John Servos on physical chemistry in America, and Colin Russell on Edward Frankland.

Brock's chapters are structured around chemical texts, chemical investigators, and schools of chemistry from alchemy through the mid-20th century. Brock criticizes some historians of chemistry for paying too much attention to conceptual confusions and difficulties over issues like atomic weights and vitalism instead of studying problems of apparatus, analysis, and reagent purity. He includes valuable information and insights about the organization of chemical laboratories and chemical education. Among his chapters on 20th-century chemistry are accounts of electron-pair and quantum mechanical theories of the chemical bond, physical organic chemistry, and inorganic chemistry. There are sections on chemistry in Australia and Japan.

The excellent and well-argued *Histoire de la Chimie* by Bensaude-Vincent and Stengers (an English translation of which is planned for 1995 by Harvard University Press) uses the theme of chemistry, or chemists, in search of an identity. This history draws as much on methods of the history of the professions or the history of disciplines as it does on the history of ideas. The authors have organized their history chronologically as five successive profiles of the identity of chemistry in different epochs, beginning with the age of alchemy. They suggest that chemistry *is* a history, rather than that chemistry *has* a history. As they put it, this history involves mechanisms of interest and mobilization, networks of alliances, and processes of selection of ideas.

If Bensaude-Vincent and Stengers depart from the other authors by using the methodology of the social construction of knowledge, there are other departures, as well, that make good points of comparison. One is that, whereas Brock emphasizes the pivotal role in the Chemical Revolution of the recognition of chemical gases, Bensaude-Vincent and Stengers emphasize Lavoisier's concern with heat or caloric. Whereas Brock makes Lavoisier and Dalton the twin heroes of the new chemistry, Bensaude-Vincent and Stengers emphasize Lavoisier as the last figure of 18th-century chemistry, rather than as the first modern chemist.

A section on the history of radioactivity raises a final point of comparison for these works. Bensaude-Vincent and Stengers argue that Marie Curie's isolation of pure

radium in the early 1900s was a kind of chemical research already belonging to the 19th-century past. Rutherford's explanation of the atomic nucleus, they argue, was creating a new image of physics in which chemistry was at the service of the physicists. Chemistry by the 1920s and '30s had been "effectively reduced to physics" (p. 309).

Knight, in devoting two concluding chapters in his history to the theme of chemistry as a "reduced" modern science with its basic principles coming from the more "fundamental" science of physics, takes a similar view. Chemistry is now a "service" science, he suggests. Indeed, Knight begins his history with the rather extraordinary statement that chemistry is a science with its glorious future behind it.

Brock is by no means so glum. He seems not to think that chemistry is physics. "Theoretical chemistry," he writes, "is still a quirky empirical science based upon a Schrödinger equation that can hardly ever be solved" (p. 505). Also not quite so generally glum as their judgment about radioactivity might seem, Bensaude-Vincent and Stengers note that the argument for chemistry as a "reduced" science ignores the history by which natural laws and theories have been negotiated *between* the provinces of chemistry and physics, not simply deduced from physics. They conclude their history with a challenge for new styles of engagement in a chemical history that is far from over.

Yet they, like the other authors, surprisingly fail to explore the ways in which some fundamental chemical concepts have been and remain distinct from physical concepts. All but Knight reflect on the power of modern chemical methods to create natural products like Vitamin B_{12} or unnatural products like C_{60}, the buckminsterfullerene soccer-ball–shaped molecule. Do these achievements represent only "service" science? The authors do not reflect on the artistic, conceptual, and practical preoccupations of those chemists who relish the individuality and uniqueness of molecules. Multiple representations of a molecule's structure and function, as well as explanations of molecular behavior that are time- and environment-dependent, distinguish a good deal of modern chemistry from modern physics.

Ironically, despite his reductionist conclusion, Knight comes closest to exploring the differences between chemistry and physics. Citing Primo Levi's literary masterpiece *The Periodic Table*, Knight writes briefly (p. 176) about some of the chemist's ways of thinking, concluding with a point of view that can be found in chemists' writings throughout the 19th and 20th centuries: that chemistry comes down to a chemical "feeling," the intuition based in experience that allows the chemist to know which reactions will and will not go.

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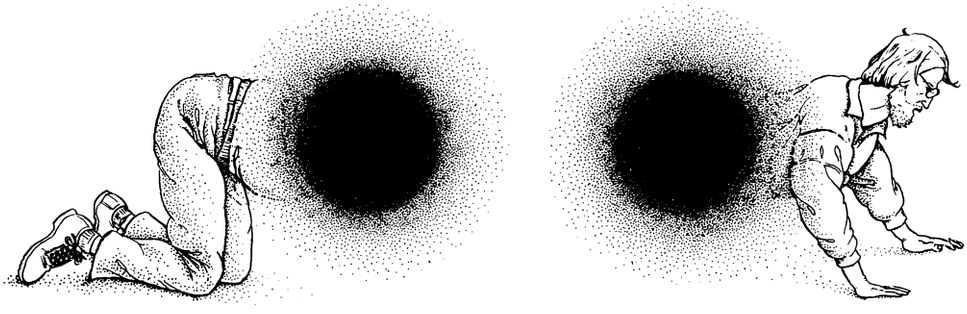
Adventures in Space-Time

Black Holes and Time Warps. Einstein's Outrageous Legacy. KIP S. THORNE. Norton, New York, 1994. 619 pp., illus. $30. Commonwealth Fund Book Program.

The theory of gravity as developed by Einstein has become a beautiful fossil. Its fate is to be worshiped by the lesser mortals who will hammer away at the more tedious details as the rare loopholes are slowly plugged. *Black Holes and Time Warps* is a hymn to the glories of general relativity. It is one of the few popular science books that I have actually read cover to cover. It has a unique style, with personal anecdotes and facts gleaned from taped interviews with the leading players intermingled with scientific explanations that are sometimes—but more often not—tough to follow.

The few post-Einstein advances, such as the search for black holes, have resulted from a collaborative effort. The relativists provided only one ingredient for the necessarily complex broth that eventually yielded a solution. Other contributors were the astrophysicists, who made realistic models, and the astronomers, who knew where and how to look. Kip Thorne is very much a gambling man, and his various wagers are frequently cited in this book. He places 95 percent odds that a black hole has already been identified. To the outsider, these odds would not warrant a game of Russian roulette, unless he or she were a fool, a gambler, or perhaps an idealistic believer that "beauty is truth, truth beauty—that is all ye know on earth, and all ye need to know." The search for beauty drove Einstein to distraction in his lifelong attempts to unify the theories of electromagnetism and gravitation. Unification of the fundamental forces—electromagnetic, nuclear, and gravitational—has indeed proved elusive. However, this has not perceptibly slowed the flood of particle theorists who work at the frontiers of gravitation theory.

Wormholes were a fad that some brave souls thought might contain the key to unlocking the ultimate secrets of nature. A wormhole is a potential tunnel from the inside of one black hole to another. Along with black holes, they are a topic beloved by science-fiction writers: A space-time traveler can emerge in the past. Thorne is one of the world's scientific authorities on time machines. In the title of his first paper on these bizarre objects he referred to them as "closed time-like loops" in order to hinder journalistic recognition—an endeavor that was successful, at least in the short term. Unfortunately, to reach a wormhole, one has to penetrate the event horizon of a black hole. This is a difficult task, as any conventional material is ripped to shreds by the overwhelming tidal forces as one approaches the horizon. Thorne instead advocates the use of naked singularities. These are horizon-free but hard to find, even in the red-light district of downtown Pasadena. Indeed, there is a conjecture due to Roger Penrose that such objects are forbidden to exist.



Kip Thorne crawling through a hypothetical, very short wormhole. [From *Black Holes and Time Warps*]