contributors use phylogenetic methods and are willing to explore new ideas without bias. Disagreements abound, but generally the discussion is refreshingly civil. The editors were able to achieve fairly uniform standards, given the diversity of viewpoints of the contributors. A modicum of pompous graffiti did sneak through in one contributor's effort, but then you can't win them all.

The book is outrageously expensive in view of the fact that the editors did most of the work and it was prepared from camera-ready copy, but it is absolutely fascinating.

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The Study of Polymers

Polymers. The Origins and Growth of a Science. HERBERT MORAWETZ. Wiley-Interscience, New York, 1985. xviii, 306 pp. $47.50.

Despite the enormous technical importance of polymers and their crucial role in living organisms, polymer chemistry makes up a very small part of the formal training of most chemists. Further, although polymers have intrigued (and plagued) chemists since the beginning of their science, the history of polymer science has had little attention.

In tracing its development since the early 19th century (the term "polymeric" was apparently first coined by Berzelius in 1833) to 1960, Herbert Morawetz makes a major contribution to this branch of the history of chemistry, since he not only has read innumerable original papers (from which he quotes copiously) but has consulted company files and interviewed surviving leaders of earlier days. The result, though not always easy reading, gives a revealing picture not only of the growth of polymer science but also of the halting and confused manner in which scientific understanding actually develops.

Indeed, from reading this book one concludes that the development of polymer chemistry was particularly halting and confused. Although polymeric natural products such as rubber and cellulose were available and were studied since the beginning of organic chemistry, the possibility of understanding their structures had to wait for the acceptance of the covalent bond model for small molecules in the later 1800's. (Morawetz gives a good account of this and of the lack of communication between organic and physical chemists of the period, with the former actively using structural concepts in their work while some of the latter still questioned the existence of molecules.) The embarrassing fact is that it actually took another 50 years and much controversy before simple covalent structures were universally accepted for polymers. E. E. Slosson's *Creative Chemistry* (1920), which introduced me to organic chemistry, still described rubber as an isoprene dimer, and Conant's *Organic Chemistry* (1934), my college textbook, still said cautiously that vinyl polymers were "probably" long linear chains. If there were villains in this controversy, they were the colloid chemists, who grouped an ill-assorted mixture of gold-sols, micelles, and high polymers together as a unique state of matter with its own laws and properties. The primary hero was Hermann Staudinger, who devoted a career to establishing the linear covalent chain structure of most polymers, but a number of others appear as well: W. H. Carothers, P. J. Flory, and H. S. Mark, to whom the book is most appropriately dedicated, to name perhaps the best known.

Not only did it take a long time for the covalent structure of polymers to be established, many other important principles had to be repeatedly restated and rediscovered. The idea that unit cells detected by x-ray scattering could be smaller than the molecules producing them was proposed by Polanyi in 1921 but was still being debated several years later. Again, cryoscopic and osmotic molecular weights of polymers were repeatedly discarded when they failed to agree with preconceived ideas, and I can still remember debates in the 1940's as to whether the solution properties of polymers arose because they were loose coils or extended ellipsoids.

Morawetz terms the period 1914–1942 the classical period of polymer science. True, by 1942 the different strands of knowledge that now make up polymer science had been largely drawn together, but the results were known only to a few (mostly European) chemists. I think the enormous impact of World War II is somewhat understated. The United States had to build a synthetic rubber industry virtually from scratch, and polymers had many other uses in the war effort. Impressive resources and manpower were thrown into polymer science, and to those who were involved the period 1943–1949 was really the golden age of polymer chemistry. Herman Mark had personally brought European polymer chemistry to the United States and through regular Saturday meetings at the Polytechnic Institute of Brooklyn was actively spreading the word and providing a center for the exchange of ideas. The theories and principles that had been advanced were being applied and shown to work, new techniques for determining polymer structure and molecular weights were being validated. The mysteries of emulsion polymerization were being unraveled, and the study of copolymerization and chain transfer in vinyl polymerization was providing a whole new basis for understanding free-radical chemistry.

Morawetz is a physical chemist, and he emphasizes the development of physical-chemical concepts: rubber elasticity, crystallinity, polymer solution properties. He seems less at home with topics such as polmerization kinetics and many aspects of polymer technology, although these are also treated. Also, in spite of his exhaustive reading of the literature, he occasionally has trouble with questions of who did what in fields where much of the original work was of proprietary nature or (during World War II) classified. To cite two examples from my own experience, he notes (p. 172) that, "ironically," no mention of mercaptans as transfer agents was made in Mayo's classic 1943 paper on the subject and (p. 185) that the fact that different polymerization mechanisms led to different copolymer compositions was first published in 1950. I can report that both phenomena were well understood by the Mayo group and others at the U.S. Rubber Company in 1943, although publication was withheld for several years.

These are minor criticisms. This is an excellent book that should be an important source, both to polymer chemists and to historians of science.

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