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Foreword

Organic Chemistry and High Technology, 1850–1950

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The melodies of Mussorgsky's 'Pictures at an Exhibition' came to mind as I contemplated the eight portraits depicting the heroic age of organic chemical science and industry from 1850 to 1950. Their inspirations were the papers presented at the Sidney M. Edelstein Center International Workshop on the History of Chemical Technology, held at the Hebrew University of Jerusalem, Israel, from 27 to 30 May 1990. Each portrait evokes its own tune; unique in both theme and historiographic approach. Each builds on previous scholarship, scrutinizes new sources, and asks fresh questions. What unites them is a renewed energy among historians to clarify how professionally driven chemical science and technology interacted and were simultaneously shaped by this era's fierce national and commercial competition.

The papers are arranged chronologically. While this is generally helpful, they can also be read profitably in any order and independently of one another. The commentary on each which follows is intended to whet the appetite with selected highlights which I found interesting. While cognizant of the risks we humans take in advancing our knowledge and transforming the world we have inherited, I approach these essays in a celebratory mood for the scientific and technical achievements recounted.

Of all the papers, the first one, Johan Schot's 'Technology in decline: a search for useful concepts', is the most theoretical. It tests Joseph Schumpeter's 'invention–innovation–diffusion' explanation of how new technologies displace the old. And it does this by examining how well this model, as refined by Nathan Rosenberg, fits the changes which threatened production of madder dyestuffs in nineteenth-century Holland. Schot concludes by proposing 'a transformation model' in which new and old technologies tend to coexist and cross-fertilize. Meanwhile, we are also treated to a word picture of the once-thriving farm culture of madder and its processing into quality dyestuffs.

While Schot disposes of simple explanations of technical replacement, Anthony S. Travis does the same with regard to the interaction between science and industry. In his essay 'Science's powerful companion: A. W. Hofmann's investigation of aniline red and its derivatives', Travis shows that in the early stages of synthetic dye manufacture Hofmann,

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the academic father of the aniline dye industry, had a research agenda that differed only subtly from that of the new industry's chemists, several of whom had been his students. While Hofmann's main concern was to elucidate the constitutions of dyes, his researches were simultaneously informed and motivated by discoveries which had been made in factories. Travis's reconstruction of Hofmann's interaction with the new dye industry will delight historical purists who insist that, before we dare launch into explanations based on hindsight, we must first learn to see the past on its own terms. For pre-Kekuléan aromatic organic chemistry, that means conceptualizing not with structural formulae but with 'Type Theory' explanations.

The commercial and institutional dimension of early dye manufacture is the focus of Henk van den Belt's study of 'Why monopoly failed: the rise and fall of Société La Fuchsine'. Among his conclusions is the interesting observation that in the 1860s the capacity of dye chemistry in circumventing process patents and in spawning new tints was so vigorous that monopolistic strategies proved unworkable in the new industry. Even more fundamental in the failure of this French combine were irreconcilable differences among its divergent owners and the determination to dissolve the company after only fifteen years, by which time its initial dye patents would have run out. The firm's woes were compounded by environmental poisoning caused by its use of arsenic acid in the synthesis of its most important product, the red dye fuchsine. Grand conclusions about the fate of the French dye industry, and even about French industrialization in the nineteenth century have been drawn by previous historians on the basis of La Fuchsine's performance. All of these now need re-examination in the light of van den Belt's research and clarification of this meteoric company's tortuous, near-chaotic history, which can hardly be taken as typical for the French chemical industry.

The challenge facing early dyestuffs manufacturers in converting laboratory discoveries into reliable and economically viable industrial processes is sketched elaborately by Willem J. Hornix's 'From process to plant: innovation in the early artificial dye industry'. Simply scaling up laboratory apparatus and bench-top procedures would not do. Dye plant designers often had to invent new appliances and, when they drew on the devices already in use among chemical manufacturers, intensive design innovations were still required to configure a workable manufacturing process. Subsequently, ongoing research and spying on competitors was essential to perfect one's process and keep it and the product competitive in quality and price. As a result of this feverish innovation, the scale and durability of factory equipment rose, manual operations were replaced by steam-powered machinery and, overall, dye prices fell as standardization and sophistication in plant design and operations developed apace in Western Europe between 1860 and 1890.

It is common knowledge that the synthetic dye industry helped to pioneer the installation of company-sponsored research laboratories. Early accounts of this important development were based mainly on secondary sources, such as company histories, supplemented by some archival sampling. With Ernst Homburg's paper, 'The emergence of research laboratories in the dyestuffs industry, 1870–1900', we are confronted with a more comprehensive, precise, and subtle account of the various ways in which scientists became increasingly useful to industry. It is an analysis based on extensive research in the archives of the largest German dye companies. Homburg ascertains that initially academically

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trained chemists were more likely than others to be hired as quality control analysts, or delegated to plant supervision and process improvement. Central corporate laboratories, staffed by chemists assigned to the discovery of potentially new products, emerged without deliberate planning among the largest firms. Yet this happened only after 1876, the year in which the German patent law went into effect, henceforth creating 'a "market" on which knowledge of organic chemistry and dye chemistry could be sold'.

The effects of German research prowess on the British economy is the focus of Peter Reed's analysis of 'The British chemical industry and the indigo trade'. When, from 1900, two German firms, BASF and Hoechst, succeeded in displacing British India, the world's main supplier of natural indigo, with the cheaper and more reliable synthetic indigo, the British Empire not only lost this important trade but itself became almost totally dependent on German supplies. Ivan Levinstein, owner of a leading British dye company, and almost certainly harbouring aspirations to develop a rival indigo process, was 'totally unable to match the R & D commitments of German manufacturers'. To level the economic playing field, Levinstein mounted an ultimately successful lobbying campaign to force foreign patent holders to work their patents in Great Britain, or grant a licence to a British manufacturer. The effect of the new legislation was beginning to revive the British dye industry when the First World War began. The conflict spurred chemical production enormously, and from it emerged a chemical industry not only much enlarged and diversified, but now also protected by a hedge of protectionist legislation. Britain's century-long commitment to free trade had collapsed.

By now we might be led to believe that dye research and manufacture had no match in other branches of chemical science and industry. However, Robert Bud's paper on 'The zymotechnic roots of biotechnology' demonstrates that such a view would be quite inaccurate. Zymotechnology, or the art of manufacturing by fermentation processes, was a term coined by Georg H. Stahl, the seventeenth-century German chemist, to affirm his faith that the new rational chemistry could illuminate such useful arts as beer brewing more usefully than the older alchemy. In nineteenth century Germany and Austria this faith was given institutional expression in the establishment of brewing academies and agricultural schools. Justus Liebig became its best-known exponent and advocate. But with Louis Pasteur's discovery that fermentation was a microorganismic process, much of zymotechnological research was reoriented towards microbiology. During the First World War this new approach to manufacturing by fermentation was used by Chaim Weizmann to help Britain overcome a critical shortage of acetone essential to the production of smokeless powder. And in Germany new forms of industrial fermentation yielded large quantities of glycerol and food yeasts. To signal that the biological approach to manufacture had growth potential that went well beyond brewing and food processing, researchers in this field came to speak of it in the 1920s as biotechnology. From this paper we can learn that well-chosen names such as zymotechnology and biotechnology can evoke the entire paradigm within which their respective researchers worked.

Our debt to Peter Morris is similar. In his analysis of 'The technology–science interaction', he helps us to understand how the industrial and academic environments influence the direction of chemical research undertaken within each, and the manner in which they interact. Specifically, he examines the discovery in 1940 of an elegant synthesis

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of cyclooctatetraene (COT) by Walter Reppe, who was then director of the central research laboratory of IG Farben's Ludwigshafen factory. It was an accidental discovery. Reppe was looking for an economical way to convert acetylene into a polyamide precursor of nylon 66. He knew that COT was of great interest in theoretical chemistry because its eight-membered ring, with alternating double and single bonds between the carbons, resembled the six-membered ring of benzene; yet, from the small amounts of COT which previous chemists had been able to make and test, it did not seem to behave like benzene and other aromatic compounds. Nevertheless, Reppe chose not to pursue the theoretical reason for this unexpected behaviour, but devoted his laboratory efforts to finding commercial uses for COT. And, when his initial optimism for the compound's utility waned, he wrote up his findings for the *Annalen der Chemie* (1948). Academic organic chemists across the world pounced on Reppe's COT synthesis and initial observation. The resulting flood of papers on the nature of and conditions for aromatic behaviour has been astonishing, rich in explanatory power and new discoveries. Organic chemists will read this account with delight. So too will non-scientists interested in understanding how the same science serves researchers differently depending on the reward system of the laboratories in which they work.

Comparing again this collection of related essays to pictures at an exhibition we observe that viewers seldom ponder long or knowledgeably the perspiration which was invested in each of the items presented, and the efforts which brought the collection together. Their attention is, rather, on the inspiration which animates each offering and on satisfying insights evoked by the display as a whole. They seek the excitement of discovering fresh ways of understanding old and new knowledge. Although the assembled essays displayed in this issue are directed primarily to readers already acquainted in some measure with chemical and industrial knowledge, their strategic perspective should enable a wide audience to discover the excitement of this fascinating and busy facet of human activity.