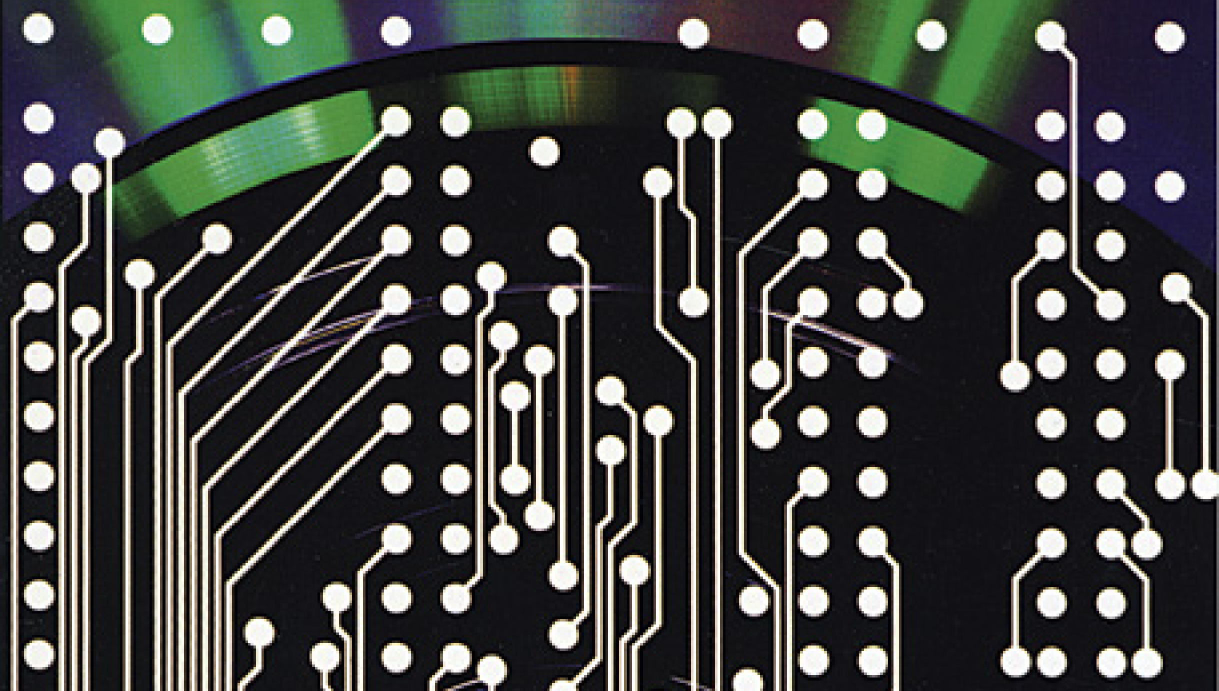
ALFRED D. CHANDLER, JR.

Inventing the Electronic Century

THE EPIC STORY OF THE CONSUMER ELECTRONICS AND COMPUTER INDUSTRIES



WITH A NEW PREFACE

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With a New Preface

Alfred D. Chandler Jr.

with the assistance of
Takashi Hikino and Andrew von Nordenflycht

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To Anne and Fay

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Many have contributed to this book but the final text is mine, and for it I take full responsibility.

—Alfred D. Chandler Jr.
Cambridge, Massachusetts
May 2001

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Preface to the Paperback Edition

This preface has two purposes. The first is to introduce this paperback edition of *Inventing the Electronic Century: The Epic Story of the Consumer Electronics and Computer Industries*, first published in the fall of 2001. The other is to introduce the project of which it is a part, Paths of Learning Worldwide, and the companion volume, *Shaping the Industrial Century: The Remarkable Story of the Evolution of the Modern Chemical and Pharmaceutical Industries*, published in 2005. In this project, I consider the evolution of the high technology industries responsible for three revolutions that so transformed life and work on Earth during the past century—the Information Revolution, the earlier Industrial Revolution, and the Biotechnology Revolution that is now unfolding.

Here I define a high technology industry as one that commercializes—makes available to the public—new products based on new scientific advances. Hence my focus on the electronics industry in *Inventing the Electronic Century* and on the chemical and pharmaceutical industries in *Shaping the Industrial Century*. The goal of both books is to understand the success and failure of the leading competitors in their respective industries in terms of technological achievement and financial success.

Inventing the Electronic Century

Only a tiny number of for-profit business enterprises created today's audio, video, and information technologies. Their story is an epic one. In audio and video technology, one company, the Radio Corporation of America (RCA), came to dominate markets worldwide by the 1950s. It did so first in audio systems, including radios and phonographs. By 1960 it had fully defined basic video technology. Then in the 1960s RCA stepped beyond its core business and attempted to commercialize mainframe computers. From there, it used acquisitions to branch into various industries, including rental cars and hotels. By 1970, this strategy of unrelated diversification destroyed RCA by diverting financial resources and management from the core business. With the fall of RCA, the U.S. audio and video industry collapsed. By the 1980s, four Japanese companies—Sony, Matsushita, Sanyo (a spin-off from Matsushita), and Sharp—dominated markets worldwide. Such a swift creation and destruction of one national industry by another in markets worldwide is unparalleled in industrial history.

The historical evolution of the information technology industry is as remarkable as that of audio and video. Only in this case, International Business Machines (IBM) has dominated the industry (including its forebears, office equipment and data processing) continuously since its beginning in 1911. Its initial products included punched-card tabulators, available globally by the 1920s. In the 1940s and 1950s, IBM helped to pioneer digital computers and software and remained in the lead as the industry moved further into electronics. By 1963, when it completed conversion from vacuum tubes to solid-state electronics, IBM's revenues reached $1.2 billion, whereas its U.S. competitors' revenues combined reached only $7.1 million.

Pouring its profits into research and development, IBM's managers and technical staff commercialized between 1963 and 1967 the System 360 mainframe computer, an extraordinary achievement. The System 360 and its successors remained the models for large-scale computers through the beginning of the twenty-first century. In 1970, however, a leading designer of the System 360, Gene Amdahl, left IBM to start his own company. Unable to finance it in the United States, he turned to Japan, thus providing Japan's fledgling computer industry with state-of-the-art technology. During the 1970s, the four major Japanese computing companies—Fujitsu, Toshiba, NEC, and Hitachi—built on this foundation to capture not only the Asian market, but in alliance with the European companies, that of Europe.

In Europe, British, French, German, and Italian computer companies, all except the last supported heavily by their governments, had struggled to commercialize large-scale computers. By the late 1970s and early 1980s, the managers in these four countries gave up. They turned to Japan to obtain their mainframes on an OEM basis; that is, to put their labels on the Japanese-made products. Germany's Siemens turned to Fujitsu as did Britain's ICL. Somewhat later France relied on NEC, and Italy's Olivetti on Hitachi. By the 1980s, these arrangements assured the Japanese dominance in Europe's large-scale computing market. IBM and the four Japanese firms also became worldwide leaders in the minicomputer and its descendants, the workstation and the server.

In the 1970s, IBM transformed information technology for a second time when it mass produced and mass marketed the personal computer initially commercialized by young hobbyists and engineers. The IBM PC and its clones, with microprocessors produced by Intel and operating systems by Microsoft, still dominate the PC market. Table 7.2 on pages 223–224 below documents the dominance of IBM and the four Japanese companies in large-scale systems, servers, desktops, and peripheral equipment such as printers and scanners in the 1990s. The table also illustrates the almost total competitive failure of the European producers. The dominance of such a small number of companies in global markets is unique in industrial history.

In reviewing the epic story of the Japanese dominance worldwide in audio and video technologies and the Japanese challenge to the United States in information technology, keep in mind the following four historical realities, for they were as central to the evolution of the Industrial Revolution between the 1880s and the 1920s as they became in the Information Revolution between the 1950s and 1990s.

First, the commercialization of new scientific learning required the combination and coordination of technological knowledge with that of product development, manufacturing, marketing, and distribution into an *integrated learning base*. The enterprises that initially created such integrated learning bases in a new technology were *first movers* that created powerful *barriers to entry* against potential competitors. The first movers enjoyed proprietary knowledge and a strong flow of income for reinvestment. Moreover, by being first, they had the advantage of lower unit costs based on the large scale of their operations. As a result, the first movers and a small number of companies that quickly followed them came to dominate worldwide markets. However, this domination continued only so long as the first movers continued to commercialize new products based on their initial competitive advantages.

Second, remaining a major competitor in a new industry required a strategy of growth to commercializing new products that were related in terms of technology and/or markets. I term this approach to growth as *the virtuous strategy* because it enabled the exploitation of *economies of joint costs or scope* as well as *economies of scale*. That is, overall unit costs are lower because related products use much the same learning and other assets in product development, production, and marketing.

Third, to be effective, a virtuous strategy, in turn, required what has been termed a *multidivisional organizational structure*. Each division became an integrated learning base for which the division managers were responsible for unit performance in terms of technical achievement and financial returns. Corporate headquarters included the senior executives who evaluated the performance of the individual divisions and planned and readjusted the overall broad strategy of the company. In addition, corporate headquarters provided a broad range of services, including research and product development, for the divisions and the company as a whole.

Finally, the alternative to growth through related diversification was, of course, unrelated diversification. By definition companies following such a strategy were unable to benefit from economies of scope. Headquarters usually consisted of senior executives and a financial and legal staff. Such enterprises, popular in the United States and Europe in the 1970s and 1980s, rarely remained profitable for more than a decade.

Similarities in the Information and Industrial Revolutions

A comparison between the evolution of the Information Revolution, discussed in *Inventing the Electronic Century*, and the Industrial Revolution, which is the primary focus of *Shaping the Industrial Century*, reveals important similarities. First, in both instances, a relatively small number of private, profit-seeking enterprises accounted for the commercialization of the new learning. Private and public universities and research institutions played critical roles in creating the broader technical knowledge, but they did not transform it into new products for everyday use. Such products came into being after for-profit enterprises had built the learning bases that integrated their technical knowledge with their product development, production, marketing, and distribution capabilities.

The second common characteristic is that these for-profit enterprises were geographically concentrated in the United States, northwestern Europe, and Japan. These areas clearly provided the most fertile environment for commercializing the new products because they were close to sources of raw material and energy, as well as to rich sources of learning in universities and research institutes. Then, even within these regions, these enterprises' activities clustered in a very few specific areas, a tiny sample of possible global industrial locations.

A third characteristic common to the two revolutions is that the for-profit enterprises that succeeded over the long term in commercializing products from the underlying technologies followed definite *paths of learning*. These paths were initially defined as the first movers, and their close followers created barriers to entry by building their integrated learning bases that enabled them to develop, produce, distribute, and sell first in national and soon after in world markets. These enterprises then reinvested and grew by expanding their original integrated learning bases and by diversifying into related technologies and or markets.

A fourth characteristic was the creation of a supporting nexus consisting of large and small enterprises supplying critical products and services required in commercializing the industry's new products, thus forming that industry's infrastructure. In other words, a nexus combining both small and large companies proved essential for national success or failure in international markets. Europe's failure in Information Technology (IT) reflects the inability to develop a nexus of small companies comparable to those of Route 128, Silicon Valley, and the multitude of small companies that existed between Tokyo and Osaka in Japan.

By the end of the 1920s, the infrastructures of both the chemical and pharmaceutical industries were essentially complete. By then the barriers to entry had become so high that, for the rest of the century, of the fifty largest chemical companies and the thirty largest pharmaceutical companies, only two new successful chemical companies and no new successful pharmaceutical companies were established. The two chemical companies were created to meet the massive new demands required by World War II.

Differences in the Information and Industrial Revolutions

The basic difference between revolutions was that the Industrial Revolution came much earlier in time and involved many more enterprises. It began suddenly in the 1880s when modern transportation and communication—that is, the completion of basic railroad networks in the United States and

Europe, the steamship, the telegraph, and the telephone—made possible mass production and mass distribution for worldwide markets. From the beginning, producers based in the Rhine Valley (Germany and Switzerland) dominated both the new modern chemical and pharmaceutical industries. However, the catastrophic effects of World Wars I and II opened the door for U.S. companies to emerge as strong global competitors. The infrastructures of both the chemical and the pharmaceutical industries were completed in the 1920s. As just noted, during the next seventy years, only two of the fifty largest chemical companies and the thirty largest pharmaceutical companies were established, and both were founded to meet the demands of World War II. Clearly the initial barriers to entry remained powerful.

The chemical and pharmaceutical industries continued to evolve in much the same manner until the 1960s. During the 1930s and 1940s, both industries received boosts from new scientific learning—chemicals, from advances in polymers and petrochemicals that also brought the major oil companies into the industry; and pharmaceuticals, from antibiotics and other new prescription drugs.

Later, the evolutionary paths of these industries began to diverge. By the 1960s, chemistry no longer proved a fertile source of new learning for commercialization. After the oil shocks of the 1970s initiated by war (in the Middle East in 1973, resulting in the increasing effectiveness of the Organization of Petroleum Exporting Countries [OPEC] cartel) and political revolution (Iran in 1979), the chemical producers undertook restructuring of their product portfolios while continuing to develop new products based on the technologies fully commercialized decades earlier, in the 1920s and again in the 1940s and 1950s. The global chemical industry underwent a major restructuring as the number of producers declined through mergers, acquisitions, and exits.

In pharmaceuticals, on the other hand, after the 1960s, biology was providing a stream of new learning. Older disciplines such as biochemistry and emerging disciplines such as microbiology and enzymology provided further product development opportunities. Then came a brand new science based on the discovery of the double helix in 1953: molecular biology and its offshoots, biotechnology and genetic engineering.

Large established enterprises initially commercialized the potential of the new science. But that commercialization required a different supporting nexus than had supported the pharmaceutical industry, and new small firms entered the fray. By the 1990s these new companies had become significant players, although not yet among the top thirty pharmaceutical companies. By then, the third major revolution, that of biotechnology, had evolved to the level of the Industrial Revolution at the beginning of the twentieth century or that of the Information Revolution in the 1950s.

The Determinants of Success and Failure in High Technology Industries

Success in terms of product innovation and financial reward in the modern chemical and pharmaceutical company was achieved in the following manner.

The critical first step in the unfolding paths of learning worldwide was the formation of powerful barriers to entry. The core companies in the respective high technology industries achieved this by devising a business strategy and a supporting management structure that enabled them to commercialize new products based on the new learning in science and engineering. The virtuous strategy entailed investing the earnings and learning from one successful product commercialization to the commercialization of another related product or by making acquisitions to accomplish the same thing. Together with the multidivisional structure, the virtuous strategy permitted the maximum exploitation of economies of scale and scope, and hence the maintenance of formidable barriers to entry.

The chemical and pharmaceutical companies that failed to follow the path of learning sketched above were acquired or merged with older companies that remained on the path.

Nevertheless, as the chemical story reveals, once science no longer generates new learning, the industry dependent on it stabilizes and matures in a pattern similar to that of most other industries whose basic parameters were established before the 1930s.

Inventing the Electronic Century