Book Reviews

The Semiconductor Industry

Revolution in Miniature. The History and Impact of Semiconductor Electronics. ERNEST BRAUN and STUART MACDONALD. Cambridge University Press, New York, 1978. vii, 232 pp. $16.95.

Braun and MacDonald have undertaken the ambitious task of documenting and interpreting the origins of the semiconductor industry, the dynamics of its growth, and the establishment of a virtual world hegemony in the field by American firms. They have succeeded surprisingly well and have produced the best monographic treatment of an extraordinary 20th-century revolution in technology that I have encountered. The semiconductor revolution and its impact have, of course, not gone unnoticed. (They were recently the subject of a thematic issue of *Science*, 18 March 1977.) The book represents a joint venture by a semiconductor physicist and a historian who are members of the Technology Policy Unit at the University of Aston in Birmingham, England. The British perspective was used to good advantage in the interpretation of technology diffusion and differences in the innovative patterns in the United States and elsewhere.

The first half of the book is devoted primarily to the introduction of the transistor, which "was not simply a new sort of amplifier, but the harbinger of an entirely new sort of electronics with the capacity not just to influence an industry or a scientific discipline but to change a culture" (p. 60). Considerable attention is given to the prehistory of the transistor and the work of R. W. Pohl, Julius Lilienfeld, Karl Lark-Horovitz, and others. The authors devote a full chapter to the Bell Telephone Laboratories and the difficult question of why the transistor was invented there in December 1947. They conclude that the transistor was not "the product of three men, or of one laboratory, or of Physics" but "required the contributions of hundreds of scientists, working in many different places, in many different fields over many years" (p. 49). The difficulties that the transistor posed for those whose education and experience were in vacuum-tube circuits and systems are well treated in a discussion having distinct overtones of Thomas Kuhn's theory of scientific revolutions. Many readers, like myself, whose electronics education was in the vacuum-tube era will recall efforts to fit the transistor into the Procrustean bed of tube theory and practice as well as the "wishing-in" and "friendly" effects that were characteristic of early transistors (p. 56).

The early dominance of the industry by Bell and the established vacuum-tube manufacturers was challenged during the 1950's by a rapid proliferation of new firms specializing in semiconductors. The authors suggest that the established firms failed fully to appreciate the importance of the small semiconductor elite, who in effect became the "free agents" of the industry and founded or worked for the new firms such as Fairchild and Transitron. As a result, leadership passed to "those who could attract, keep and make best use of these individuals" (p. 72). A decisive role in the early success of many of these firms was played by the existence of a military market that was receptive to the latest products and not overly concerned with price. New manufacturing processes such as the planar technique introduced by Fairchild Semiconductor in 1958 brought about an enormous increase in productivity and fierce price competition. This precipitated a crisis in the early 1960's that was resolved at least temporarily by a new product innovation, the integrated circuit.

The second half of the book is devoted to the second phase of the semiconductor revolution, in which the transistor and discrete components were supplanted by the integrated circuit. What had seemed to be a predictable evolutionary pattern of miniaturization was shattered abruptly by the introduction of processes that made the integrated circuit the winning contestant among the alternative paths to microelectronics. In a chapter on the American semiconductor industry, the authors provide a fascinating explanation of synergism that resulted from the location of numerous firms in "Silicon Valley" near San Francisco. A key element both there and along Route 128 near Boston was the ready availability of risk capital controlled by a "new breed of men, expert in both financial affairs and electronics" (p. 128). Geographical proximity also facilitated rapid transfer of experts and information, often in the informal setting provided by the Wagonwheel Bar, where "semiconductor men drank, exchanged information and hired employees" (p. 127). The market value of the expert "job hopper" was sometimes measured by the Hogan unit, defined in terms of the large remuneration received by Lester Hogan when he left Motorola to join Fairchild (p. 132). It was even suggested that an effective strategy for foreign competitors might be to establish a plant in Silicon Valley in order to take advantage of the intangible factors that had helped make the area a seedbed of innovation.

In the final chapter, "Reflections on an electronic age," the authors discuss such manifestations of the semiconductor revolution as the pocket calculator and speculate on the future. They consider such issues as the "technological imperative" of semiconductor devices, "technology-push" versus "market-pull," and the paradox that the cheapest product may sometimes be the best. They note the generally poor record of those who have tried to forecast developments and impacts in the industry. They mention but do not dwell on the "potentially sinister aspects" of the misuse of electronics and computers (p. 196).

The analysis is well supported by graphs and tables and by frequent quotations from participants in the revolution. A historiographic caveat is that the authors do not discuss their interview procedure or tell whether transcripts of the interviews are accessible to others. The authors have not attempted to link their findings to the literature on earlier technological or scientific revolutions, perhaps in keeping with their expressed desire to "avoid collision with the theorists of invention and innovation" (p. 38). Consequently, they have neglected suggestive parallels with the well-studied American System of Manufacturing of the 19th century and related analytical concepts such as technological convergence introduced by Nathan Rosenberg. Hugh Aitken's recent monograph on the origins of radio also contains concepts and insights that might have enriched this study.

This book deserves a wide readership both among those who have a professional interest in public policy issues involving high technology and among those who are merely curious about the roots of the ubiquitous pocket calculator or apprehensive about a future dominated increasingly by computers and electronic technocrats. It should be of particular interest to students of the history and sociology of 20th-century science, technology, and business and of technological revolutions in general.

JAMES E. BRITTAIN
Department of Social Sciences, Georgia Institute of Technology, Atlanta 30332

Perceptual Constancy

Stability and Constancy in Visual Perception. Mechanisms and Processes. WILLIAM EPSTEIN, Ed. Wiley-Interscience, New York, 1977. xiv, 464 pp., illus. $22.50. Wiley Series in Behavior.

This book is organized around one of the major problems of classical perceptual research: how we perceive the objects and events of the visual world as stable despite the physical fact that the light at our eyes is continually changing.

The problem itself is not self-evident: Inasmuch as the surface colors (reflectances), sizes, shapes, and other attributes of objects are relatively stable, why should we be surprised that we perceive them so? To understand why, we must first distinguish the physical objects and their properties, which are distal stimuli, from the proximal patterns of stimulation the objects present to the sensory receptors in the eye. Under given viewing conditions, the size, shape, and luminance of the proximal stimulation that is provided by an object are determined by the object's size, shape, and reflectance. Change the object's distance, inclination to the line of sight, and illumination, and the size, shape, and luminance of its proximal stimulation change. In fact, subjects usually report that two objects appear equally light, say, or large when they are more alike in distal reflectance and size than in proximal stimulus pattern. On what information and by what processes, then, does the viewer identify the invariant object properties by means of varying stimulation?

The problem is methodologically attractive. Proximal and distal variables are usually relatively easy to vary independently and to measure precisely. And the theoretical issue is surely important. But the nature of the problem that is posed depends on our theory about how sensory information is extracted from the proximal stimulus pattern.

One approach to the problem, which yields the solution that is still favored by many or most psychologists, is that of Hermann von Helmholtz, who, as Johannes Müller's student, undertook the task of analyzing perception in terms of the unitary receptors or "specific nerve energies" available to each sensory modality. To Helmholtz the visual response to the proximal stimulus pattern was the independent activities of the photoreceptors in the retina and the set of individual sensations of color that accompany these. Our sensations of an object thus vary as the proximal stimulus varies, as it does with changing viewing conditions. We perceive stable object properties because we have learned to take into account the conditions of viewing, that is, whatever indications of distance and illumination are contained in the proximal stimulus pattern. "Taking into account" is a process similar in its general results to inference or syllogistic reasoning, except that it is unconscious. Most useful to this process are the sensory "experiments" on which each viewer bases his or her unconscious inductions: "By our movements we find out that it is the stationary form of the table in space which is the cause of the changing image in our eyes," Helmholtz wrote in *A Treatise on Physiological Optics*. Because distal object properties, not changing proximal stimulation, are important in our lives, we normally find it difficult to notice the changing sensations. We perceive instead those objects and events that would have been most likely under normal viewing conditions to produce the sensory impressions we have received.

Other approaches explain sensory response to proximal stimulation differently. If our receptor systems respond to the ratio of luminances between an object's image and its surround, and not to the absolute luminance of each, our responses would normally remain stable with the object's reflectance. Much of the reflectance constancy that our perceptions display could then be explained (as Ewald Hering and Ernst Mach proposed) without reference to processes such as "taking into account" or to the necessity of perceptual learning. It is easy to imagine neural circuitry that could accomplish such sensitivity to ratios of adjacent luminances, and some suitable circuitry has actually been found. The issue of perceptual constancy therefore intersects with the general nature-nurture issue, but it need not. Even if reflectance constancy is a result of learning, it might be a result of learning to attend to the ratio, not of unconscious inferences from mental structure.

More generally, we might hold with J. J. Gibson that by innate endowment, perceptual learning, or both, we extract the constant object attributes that provide a mathematical invariant that undergoes transformations in the changing proximal stimulation. According to this view, we respond directly to the invariant in the flux of changing proximal stimulation that specifies a table in space as we move around it and not through the working of any additional inference-like process. This is thus a holistic direct perception theory.

In the book under review, William Epstein provides thoughtful first and last chapters discussing the history and theoretical importance of the constancies and summing up contemporary findings along lines similar to those I have developed here. He concludes that both kinds of explanations are needed by the data and that both should be pursued.

Wayne Shebilske reviews recent research on the apparent stability of the apparent locations of objects in the field of view despite movements of the eye or head and concludes that neither a "taking into account" theory based on nonvisual (motoric) information about the direction and extent of movement nor one in which the stable distal stimulus is extracted as the invariant undergoing translation will explain the data. Sheldon Ebenholtz argues that something very much like Helmholtz's unconscious inference—what Ebenholtz calls an algorithm-processing approach—is manifested in the constancy of objects' apparent orientation despite changes in proximal orientation (such as is caused by tilting the viewer). Hiroshi Ono and James Comerford consider possible models to account for the perception of depth resulting from binocular disparity and the constancy of depth perception over different distances (the visual system must take viewing distance into account in assigning a definite depth to a particular disparity in the two eyes' views of an object) and find that there are too few data to decide between the models. Walter C. Gogel presents a great many data to support the familiar distinction between absolute ("that table is six feet away") and relative ("that table is nearer than that wall") sources of perceptual information and shows that they are often in conflict—a point difficult for a holistic direct perception theory to accommodate.

Although these five chapters are concerned more with describing fields of data than with what I believe to be the most important theoretical differences between the different classes of ex-