

GDR science can only be achieved if the information found in these archives is contrasted with eyewitness accounts. The importance of interviewing surviving participants is underscored by the story of the 1-megabit chip. Friedrich Naumann's chapter (in the German edition only) about computer science and technology in GDR still identifies "the completion of the first functioning model of the 1-megabit storage chip by a collective of the combine Carl Zeiss Jena" as a "milestone" and an example for "performances that deserve unconditional respect." In contrast, Macrakis's chapter about espionage reports that "by the time the wall fell, the GDR had not produced any 1-megabit chips. It turned out the sample was just a dummy acquired from the West." Even the Stasi files lack evidence for this conclusion (which does not really surprise insiders), but it is backed by an interview with a former Stasi officer.

Science is made by people, and the books gain another dimension through their biographical chapters. One describes the singular story of Robert Havemann. As a communist and resistance fighter, he was sentenced to death by the Nazis. He later became a stalinist and reached a very powerful position in the GDR during the 1950s, but turned into a dissident in the 1960s. The life of the psychologist Kurt Gottschaldt is less known, but no less peculiar. He managed to adapt his career (and his science) to the rise of the Nazis and the later political change to socialist Germany. After conflicts with his institute, the party, and state officials, he left in 1962 for West Germany, where he finished his career. The German edition also includes a chapter on Friedrich Möglich, who lived and worked through the Nazi years and in the GDR until 1957.

The books are most fascinating where they report facts precisely, compare developments, and reveal connections. The emerging picture—though far from complete—is compatible with what I witnessed as a student in high school and university and as a researcher in the academy. The various authors provide different degrees of interpretation from different points of view. Much effort is made, not least by Macrakis, to be fair: "nor did we follow the well-worn thesis of the adverse effects of authoritarian political ideology on science." One author warns that "the very fact that the GDR as a state came to an end can seduce a historian into viewing its history teleologically." All these precautions and warnings do not help. After having read chapter after chapter, no reader will escape the conclusion that this political system—with the way it ran science and the economy and the way it wasted human resources—is bound to fail when high technology becomes a necessity.

Someone trained in Marxist dialectics would conclude that the GDR's system

collapsed from its own antagonistic contradictions. This conclusion emerges even from the facts reported by an author who views the reforms of the science system in the 1960s as a "failed reform experiment" and who still believes that the GDR could have been saved had only "the opportunity to initiate and implement substantial reforms...as a means of transforming society" not been missed. I do not think that anybody who reads these books would wish to participate in another "laboratory experiment" of this kind.

References and Notes

1. Besides differences noted elsewhere in the review, the U.S. edition includes an introductory chapter that offers an interpretive analysis of GDR science, while the German volume has a prologue that provides a short overview of the chapters. An account of computers and politics is restricted to the English version, and the German book contains an extensive bibliography (current to mid-1997).

BOOKS: PHYSIOLOGY

Wondrous Senses

Richard Gregory

The variety of sensory systems that provide signals beyond human experience stretches our imagination, and the search for explanations of how such systems function challenges our most sophisticated technology. Among these systems are the sonars of bats and dolphins, the recognition of patterns of polarized skylight by bees, the magnetic compasses that contribute to global migration by birds, and the use of electric field distortions for orientation and prey detection by fish that inhabit murky waters. Many of these abilities are also linked to communication, as in the waggle dance of bees (which signals the direction and distance to nectar by reference to the sun).

Sensory Exotica is a journey into how surprising discoveries have been made; the contributions of key individuals are described with sufficient, though not overwhelming, technical detail. Hughes, a professor of psychology at Dartmouth College, writes with the enthusiasm of a gifted amateur (in the best sense) whose search of the scattered literature has found so many treasures to share that he entralls the reader. He offers a personal account of his search (rather, perhaps, than research), but he sticks to the known facts, and his occasional spec-

ulations and comments on the nature of science itself are not intrusive. The author's discussions are further enriched by the attractive and informative illustrations.

Hughes relates, with appropriate detail, the remarkable ability of bats flying in complete darkness to avoid fine wires even in the presence of a thousand other bats using sonar at the same wavelengths. He also discusses the ability of bees to navigate when the sun is not visible. His account (which assumes almost no basic knowledge) starts with the physics of polarization, describes how light is polarized by atmospheric particles, and leads to a summary of the special adaptations exhibited by the receptors of the honeybee's eye. Particularly intriguing is how the bee achieves what looks like complicated computing to use the sky-polarization patterns. Computing in the brain is avoided because the eye's anatomy solves this special problem in an analog way. This surely has lessons for artificial intelligence and how we should think of neural processes of the human brain: specialized analog modules that avoid computing seem to be very important. (The pattern recognition and adaptive learning capabilities of tiny insect brains also challenge artificial intelligence because man-made computers can now simulate appropriate numbers of active neurons.)

These themes are not, however, developed in the book, which has little on the central integration of signals or how they may be read in terms of behavioral needs. It might be said that "simple" animals have complex senses designed to avoid high-level signal processing; whereas our eyes, for example, are far less sophisticated because our brains can handle—and need to, for our greater range of behavior—relatively raw unprocessed data to deal with a wider range of selections. Although the author does not explore the processing required for behavioral demands or the relations between the kinds of signals available from senses, he offers plenty to think about.

The wondrous capabilities that Hughes discusses are only beginning to be understood. One obstacle to progress has been the need to isolate overlapping senses when several are used to complement one another. (This is a particular problem for bird navigation, in which different senses are used when one or more are inoperative.) But the challenging questions could attract anyone with a sense of curiosity and skills in biology or information technology (some knowledge of both would seem important). *Sensory Exotica* may inspire budding scientists to pursue this rich field of inquiry.

Sensory Exotica A World Beyond Human Experience by Howard C. Hughes

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