a brief courtship the author had with physics as a possible vocation. The immediate impetus was apparently the willingness of a young physics teacher of philosophical bent to take seriously the intellectual eagerness of a student whom chemistry teachers had, not surprisingly, left unstimulated. This reviewer, who a few years earlier had found among Italian physicists the intellectual stimulus liberating him from a humdrum medical education, can vouch almost to the last comma for the authenticity of the experience described by Levi.

"Arsenic" is a vignette that could easily have been turned into a crime investigation in the hands of a less sensitive author. One of his first clients brings to Levi a pound of sugar which he suspects of having been doctored. Levi analyzes it and finds plenty of arsenic. For the rest of the day he goes on with other work. Next day the client returns, hears the verdict, explains calmly that a competitor—a cobbler like himself—has been making his life hard and now has apparently attempted to poison him. No fuss, no police; the cobbler, a quiet Piedmontese, will return the sugar to his enemy and "explain two or three things" to him. Levi's philosophy of constructive faith in reasoning reminds me, here and elsewhere in the book, of Diderot's trust in human common sense.

"Vanadium" is the story of a more recent event. While dealing with a German firm concerning a batch of imported resin (which misbehaved because of a vanadium salt impurity) Levi discovered that his German correspondent was the same man who had been his boss in the Auschwitz camp. The exchanges that ensue illustrate the conflicts of an honest man divided between the forgiveness demanded by personal self-respect and the contempt felt for a Nazi colleague—truly an impurity in the scientific milieu.

In all 18 essays the writing has an immediacy achieved without sacrifice of sophisticated literary skill. The English translation manages to keep the freshness of the original Italian best seller. Primo Levi succeeds in transforming chemical concepts and processes into metaphorical comments on life. He also achieves the more difficult feat of writing autobiographical stories without either self-effacement or self-congratulation. These essays are in fact, as the author calls them in the essay called "Nickel," "tales of militant chemistry."

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Visual Neurobiology

Development of Visual Pathways in Mammals. JONATHAN STONE, BOGDAN DREHER, and DAVID H. RAPAPORT, Eds. Liss, New York, 1984. xvi, 489 pp., illus. $68. Neurology and Neurobiology, vol. 9. From a symposium, Sydney, Aug. 1983.

Until a few years ago, a good deal of what was known about the development of the brain came from studies of lower vertebrates, where it has been methodologically feasible to examine the events associated with the initial outgrowth of neural pathways and with regeneration of pathways following damage. Recently, however, a remarkable amount of new information about brain development in mammals has become available. Not surprisingly, a good deal of this information is concerned with the development of the mammalian visual system, a favorite subject for developmental neurobiologists because of the relative wealth of knowledge concerning the details of visual system organization in adult animals.

Development of Visual Pathways in Mammals is a collection of 30 or so contributed papers written by some of the participants at a meeting. Although its title conveys the impression that it is largely about visual system development, the book is divided into four sections, of which only the first two, on the mammalian retina (section 1) and central visual pathways (section 2), are specifically concerned with development. An equal portion of the book is devoted to the modification and recovery of the visual system from the effects of damage or surgical manipulations (section 3) and to abnormal visual experience (section 4).

Several themes recur throughout the book and play upon each other. One is that the adult pattern of visual system organization is not established during development but emerges following an extended period in which an immature pattern is progressively reorganized by a combination of regression and addition. This is true of the mammalian retina, where the adult central-to-peripheral variation in ganglion cell density is sculpted out of an initially uniform distribution by a process of selective cell death, as is discussed in papers by Stone *et al.*, Dreher *et al.*, Perry, and others. It is also true of the development of connections within the central visual pathways, in which the adult pattern of restricted and segregated inputs only emerges following a period during which excessive connections are made and then refined by collateral retraction or cell death (retinofugal connections are discussed by Chalupa and Williams, Sanderson, Godement, and Friedlander, and connections of visual cortex are discussed by Tsumoto *et al.*, Rhoades *et al.*, and Innocenti). A related theme is that the mammalian visual system at birth is actually surprisingly immature both anatomically and functionally, presumably because the events described above are not yet complete. Cat retinal ganglion cells (Ikeda and Robbins), lateral geniculate nucleus neurons (Friedlander), neurons of the superior colliculus (Stein), and corticotectal neurons (Tsumoto *et al.*) all undergo considerable postnatal development to attain their adult properties. The immaturity present during early postnatal life is also likely to contribute to the ability of the visual system to recover from surgical manipulations performed early but not later on in life (Kalil, Spear, Weller and Kaas) and from transplantation experiments (Harvey and Lund, Cunningham and Haun) and to the susceptibility of the visual system to the effects of abnormal visual experience on neurons (Wilson *et al.*, Leventhal, Crewther and Crewther, Timney, Hirsch, Murphy, Blakemore and Vital-Durand) and the consequent ability of the visual system to recover visual behavior and cortical function (Mitchell and Murphy, Van Sluyters and Malach).

Although a direct link must exist between the postnatal period during which visual connections develop to maturity and the period during which connections can be modified by various circumstances, the papers discussed above provide disappointingly little specific information on this point. Indeed, the sections on development are dissociated from the sections on the modifiability of the visual system by a conceptual and informational gap, which presumably was bridged during the meeting itself. In this regard it is worth noting that the contents of the book by no means cover all that is known about the development of visual pathways in mammals. Conspicuously absent is the entire subject of the role of neuronal activity (including synapse formation and neurotransmission) in the development and modifiability of visual system connections—a subject that has generated much interest and excitement in recent years and is of considerable relevance to all of the studies discussed above. In addition, a good deal is now known about early developmental events such as those associated

with the initial outgrowth of retinal ganglion cell axons and with the neurogenesis and migration of cells that make up the visual system and other events that occur largely during prenatal development but are now amenable to study because of significant technological advances. These omissions weaken the book and make it less suitable for the reader seeking a comprehensive introduction to this field. However, those working in the field will find the book useful not only as a source of information, but also as a reminder that much more must be learned before it is possible to understand fully how connections in the visual system can be altered by the effects of experience.

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A Science of Cognition

Method and Tactics in Cognitive Science. WALTER KINTSCH, JAMES R. MILLER, and PETER G. POLSON, Eds. Erlbaum, Hillsdale, N.J., 1984. xii, 324 pp. $29.95. From a conference, Boulder, Colo., 1981.

Methods are justly notorious for the barriers they can impose between adjacent sciences. It is therefore not surprising that the recent movement to integrate the several sciences of cognition has encountered its most stubborn obstacle in the diverse methodologies employed in psychology, linguistics, computer science, neuroscience, and the rest of the cognitive sciences. This book is a valiant effort to confront the problem.

Authored by about a dozen cognitive scientists of various stripe who met together in a conference, the book keeps its bearings by working from concrete examples of research in artificial intelligence (AI), linguistics, and cognitive psychology. In each chapter, the authors attempt to illustrate the methods employed in their particular corner of cognitive science and to assess the relations between their own methods and those of their near neighbors. Kintsch, Miller, and Polson provide introductory and concluding chapters that summarize the entire exercise.

Collectively, the authors are of three minds about the current relations among the methodologies and their future prospects. One camp argues that certain methods are inherently more powerful and will come to dominate the field. Philosopher John Haugeland, for instance, maintains that AI is "first among equals" because computers make it "feasible to build, maintain, and intellectually manage systems of unprecedented complexity." Therefore, Haugeland argues, AI can attempt to synthesize the full scope of human intelligence, whereas each of the other cognitive disciplines is stuck with "some little tag-end of the phenomena that it can get a relatively firm grip on" (p. 92). A second camp, principally represented by computer scientist Eugene Charniak but also including the editors of the volume, argues that methodological diversity is cognitive science's greatest current asset. Since all efforts to understand the workings of intelligence remain fairly primitive, cognitive scientists should not attempt to prejudge which will evolve most successfully. Meanwhile, tolerance and an effort to understand each other's methods should be the order of the day. The third camp takes a somewhat stronger line: namely, that the disparate battery of cognitive methods can be employed in complementary fashion to achieve a science of cognition that is more successful than any of the current cognitive sciences alone can be.

Of the three views, the last is undoubtedly the most interesting, since only in it is there any promise that cognitive science might become more than the sum of its parts. Anyone interested in assessing this promise should look particularly at the chapter by Bresnan and Kaplan, which sets forth the methodological program underlying lexical functional grammar, and also at the chapter by Van Lehn, Brown, and Greeno, which reviews the so-called "buggy" studies of children's problems learning multiplace subtraction problems. Bresnan and Kaplan argue that linguistic criteria alone are not sufficient to determine a psychologically valid representation of linguistic competence. In their view, a grammar must be usable, learnable, and psychologically testable in order to stake a psychological claim, and they try to show how lexical functional grammar might meet these tests. Van Lehn, Brown, and Greeno similarly argue that isolated cognitive methods are insufficient, but their target is AI, not linguistics. In their view, AI's efforts to simulate intelligent behavior are in danger of simply substituting "one black box, a complex computer program, for another, namely the human mind" (p. 237). Computer science may have given psychology the means of expressing detailed cognitive models, but this increased representational capacity has not been matched by efforts to analyze the principles underlying intelligent behavior, either natural or artificial. As a result, "the new, richly detailed models of cognitive science often fail to meet the traditional criteria of scientific theories" (p. 237). Van Lehn and colleagues recommend that the theoretical techniques of linguistics and the experimental techniques of psychology be added to AI in order to develop testable claims about the underlying nature of intelligence. Certainly, one comes away from this book with an enhanced sense of the methodological options available in the cognitive sciences. But one also emerges with a sense that it matters, perhaps more than previously supposed, whether we think of the cognitive sciences as one or many.

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(Continued on page 100)