Not everyone will agree with Cheney and Seyfarth's conclusions. However, anyone who now seriously intends to disagree will have to read this book.

ALISON JOLLY
Department of Ecology and Evolutionary Biology, Princeton University Princeton, NJ 08544–1003

Cognition as Search

Unified Theories of Cognition. ALLEN NEWELL. Harvard University Press, Cambridge, MA 1990. xx, 549 pp., illus. $39.95. The William James Lectures, 1987.

For cognitive scientists, the William James lectures by Allen Newell were the sensation of 1987. The videotapes circulated widely and there were seminars and discussions everywhere. This book version, though intensely personal, provides an unparalleled view of the outlook, accomplishments, and aspirations of information-processing psychology and the articulating aspects of computer science.

Remarkably, after nearly 40 years Newell's sense of wonder and excitement is palpable. The book opens by celebrating the idea of the universal computer that can simulate arbitrary problems coded in symbolic form. But Newell's core concern has always been the prospect of explaining the human mind using the conceptual tools of computer science. The thesis of the book is quite explicit: the best approach to understanding human cognition is the construction of unified theories based on abstract information-processing concepts. The central notion is that all of cognition can be viewed as "search in an appropriate problem space." Particular domain theories are to be expressed as collections of rules written in a uniform notation and interpreted by an "architecture" whose properties constitute the tenets of the general explanatory theory. These ideas are made concrete through the example of Soar, an architecture that Newell and his students have been developing for about a decade.

Soar is an evolving collection of simple but powerful information-processing constructs. All of the knowledge in Soar is represented as situation-action rules of the form: if *this* is in working memory then do *that*. Any computation can be expressed this way, and the notation is used in many applied expert systems. What is unique in the Soar architecture is the way in which the rules are controlled, particularly in the case where two or more of them conflict. In Soar, all applicable rules (even contradictory ones) can operate simultaneously, but all they can do is add new tentative information to the working memory. If this does lead to conflicting data being placed in working memory, Soar treats this impasse as a subproblem to be solved next. The system has strategies for choosing subgoals and completing or abandoning them. One other fundamental feature is a simple learning mechanism called "chunking." Under appropriate conditions, a chain of rule applications is chunked into a single new rule, often in a generalized form. Since most of Soar's strategies are expressed as rules, these also benefit from chunking.

For Newell, Soar helps achieve unified theories in two ways: it provides coherence through the use of a uniform notation and of a fixed architecture. Ideally, all of the rules for different domains would cohere, forming a model of intelligence that would be greater than the sum of its parts. This is an attractive prospect and is essentially the vision that launched the information-processing movement in cognitive science. The program has, however, recently come under attack for its detachment from any underlying physical reality.

Obviously enough, the Soar architecture is too abstract to be mapped directly to brain structure even at a very coarse grain. Newell's move here is brilliant. Instead of trying to ground the theories in brain structure, he focuses on human performance, particularly timing. Taking the millisecond-range computing time of neurons as basic, Newell constructs a hierarchy of timed processing levels, assuming that each level takes about ten steps of the level below. The resulting time estimates are used in constraining particular theories to be consistent with the wealth of chronometric experimental data on some tasks. The hierarchy also provides the argument that human cognition is best modeled at the knowledge level independent of implementation details.

With the framework laid out, the remainder of the book supports the case for unified theories by modeling as many phenomena as possible in the paradigm. A complete task model requires input and output analysis, and this forces Newell to apologetically introduce black-box theories of perception and motor control. He can then exhibit models of well-studied immediate response tasks such as typing and the Sternberg item-recognition task. Moving to a somewhat higher level, he outlines the Soar approach to memory and learning. The most detailed analysis, of nonsense-syllable recall, illustrates how chunking can be specialized for a specific task and how Soar can be used to recreate classical models. There is also a nice discussion of why Soar chunking is consistent with the ubiquitous power law of practice. The next chapter focuses on three complex problem-solving tasks: cryptarithmetic, logical reasoning, and a very simple sentence-verification task. Each is used to illustrate a different general aspect of Newell's theory of cognition as search.

As the author states, these modeling efforts have varying degrees of depth, success, and coverage. But taken as a whole they constitute the most impressive treatment by far of such a wide range of findings. Some readers will find the results unsatisfying because there is still no notion of how the brain actually does all these wonders. But the challenge of unified theories at the knowledge level has been laid down. More biologically oriented theoreticians will have to do better or will need to map Soar to more brain-like architectures. Taking this challenge seriously will lead to significant advances in cognitive science.

JEROME A. FELDMAN
International Computer Science Institute, Berkeley, CA 94704

Left Brain, Right Brain

The Decline and Fall of Hemispheric Specialization. ROBERT EFRON. Erlbaum, Hillsdale, NJ, 1990. xvi, 117 pp., illus. $19.95.

The current popular obsession with the "left brain, right brain" duality is not a new phenomenon. There was a similar wave, now largely forgotten, in the latter part of the 19th century following discoveries that the psychological effects of brain injury depended very much on which side of the brain was injured (see A. Harrington, *Medicine, Mind, and the Double Brain*, Princeton University Press, 1987). Then, as now, speculation owed more to enduring myths about left and right than to the empirical evidence.

The new wave began in the 1960s when testing of the so-called "split-brained" patients, who had undergone commissurotomy for the relief of intractable epilépsy, again dramatically revealed the brain's functional asymmetry. As a consequence, notions of hemispheric duality have spread far beyond the scientific journals and into popular culture. If history is to be our guide, this new wave must also soon come to an end, and the volume under review reflects a growing skepticism about the importance and validity of hemispheric specialization.

In spite of its title, however, Efron's slim book will not slay the beast and may strike no more than a glancing blow. It consists of only three chapters, based on a series of invited lectures delivered in 1989 at the University of Alberta. Efron deals with only very limited aspects of cerebral asymmetry and makes no attempt to review the voluminous literature on it.

In his first chapter Efron reminds us that the different effects of left- and right-sided brain damage need not imply that the two sides are differently specialized. He uses an analogy suggested by F. M. R. Walshe: If the tooth of a gear in an automobile transmission system has been knocked off, there is a "thunk" every time the drive shaft turns, but one does not conclude from this that the tooth is specialized for preventing thunks. It is true that neurologists and neuropsychologists have often been uncritical in localizing functions in the brain, and Efron's reminder is not untimely. Nevertheless there can be no denying the striking asymmetries of the human brain, even if the concept of hemispheric specialization is itself suspect.

The second chapter focuses on two techniques that have been widely used to study asymmetries in normal people as well as in the split-brained. One is dichotic listening, in which different inputs are fed simultaneously to each ear and an advantage in reporting the input to one or other ear is interpreted as a dominance of the other cerebral hemisphere. For example, a right-ear advantage for verbal material is taken as evidence for a left-hemispheric dominance for language. The other is the visual-hemifield technique, in which visual information is flashed to one or the other side of the point of visual fixation and an advantage to one or other side is again interpreted as evidence for dominance of the opposite hemisphere. Efron is rightly critical of the cottage industry that has developed around these techniques, flooding the literature with low-cost, easy-to-run, sure-fire experiments whose cumulative influence has probably been toward chaos rather than enlightenment.

But in his critique Efron has ignored many of his predecessors. For example, in criticizing Doreen Kimura's "structural" theory of how asymmetries in dichotic listening come about, he points out that attentional biases may play an important role. This was clearly recognized in the early 1960s by Marcel Kinsbourne, and the relative roles of structural and attentional influences have provided what has probably been the dominant issue in dichotic-listening research for nearly 30 years. Yet Kinsbourne is never mentioned.

Similarly, Efron points out that the asymmetries between the visual hemifields may be due to scanning habits rather than to hemispheric specialization, and the role of scanning is explored in some detail in the final chapter, entitled "Life after hemispheric specialization." But again the basic message is not new. The idea that visual-hemifield asymmetries are due to scanning was the prevailing one in the 1950s, and most of the early investigators were at pains to rule out scanning in arguing for hemispheric differences. To be sure, Efron's work is of some interest in its own right and may force researchers again to take scanning explanations seriously. But, as before, he has ignored earlier, related work by George Sperling, Charles W. Eriksen, and others, as well as the proliferation of recent work on visual attention initiated by Michael I. Posner.

In substance, this book is little more than an extended article summarizing Efron's own work on spatial effects in vision and hearing. The work is often interesting, but for the reader who wants a general update on left brain, right brain dualism the best thing about the book may turn out to be its title.

MICHAEL C. CORBALLIS
Department of Psychology,
University of Auckland,
Auckland, New Zealand

The Bottom of the Sea

The Deep Sea Bed. Its Physics, Chemistry and Biology. N. CHARNOCK, J. M. EDMOND, I. N. MCCAVE, A. L. RICE, and T. R. S. WILSON, Eds. The Royal Society, London, 1990. viii, 194 pp., illus., + plate. £ 42.60. From a meeting, London, April 1989.

The deep sea floor and its associated boundary layer have long been perceived as a remote and exotic environment: an ecosystem largely uncoupled from the physical and biological dynamism of the upper ocean. In this view, sunlit surface waters primarily contribute a gentle rain of small, food-poor particles to the cold and dark abyssal reaches, forcing chemical and biological processes at the seabed to proceed at very slow, steady rates. This perception pervades reviews of deep sea research published as recently as 1983. *The Deep Sea Bed: Its Physics, Chemistry and Biology* is not the first publication to dispel the notion of a slow, steady, isolated ecosystem. However, this collection of loosely related papers does highlight a number of research programs of the past decade that demonstrate the deep sea bed to be an integral, and at times dynamic, component of the ocean system.

Three major themes emerge from this collection. The first is that significant physical, chemical, and biological interactions occur between the upper ocean and the deep sea bed on time scales of days to millennia. For example, seafloor "storms" driven in part by surface flows (Richards; Gross and Nowell), pulses of spring-bloom "phytodetritus" reaching the seabed (Gooday and Turley), and upward fluxes of buoyant particles (Angel) all suggest a surprisingly rapid exchange of energy and materials between surface waters and the abyss. Important interactions between the upper ocean and the seabed are also indicated on longer (thousand-year) time scales by the modeling efforts of Sundquist, which suggest that 40 percent of the ocean's ability to buffer atmospheric CO_2 concentrations is controlled by deposition, precipitation, and dissolution of carbonates in deep sea sediments.

The second major theme of this volume is a corollary of the first; given relatively rapid exchange between surface waters and the abyss, the dynamism of the upper ocean is clearly manifested in seafloor processes. For example, several authors (Gooday and Turley; Jumars *et al.*) outline how the feeding behavior, growth, and reproduction of deep sea organisms ranging from bacteria to brittle stars may rely on rapid utilization of seasonal pulses of food-rich phytodetritus to abyssal sediments. In another paper, Hill and Nowell conclude that large, fast-sinking particles (or "marine snow") may contribute substantially to the clearing of near-bottom nepheloid layers. Because pulses of marine snow are produced during phytoplankton blooms, one might conclude that nepheloid clearing rates may track primary production cycles. Clearly, such linkages between upper ocean dynamics and seabed processes will be intensively studied by deep sea scientists in the coming decade.

A third common thread running through the more exciting papers in this volume is the combination of quantitative models with innovative measurement programs. This is well illustrated in the papers by Emerson and Archer and by Wilson and Wallace, who independently demonstrate that the dissolution rate constant for $CaCO_3$ in deep sea sediments must be 10 to 100 times smaller than has been surmised from laboratory studies; their findings may have important implications for models of CO_2 cycling in the global ocean. Aller's work also demonstrates the power of combining models with measurements by showing how particle reworking by sediment-dwelling animals (or bioturbation) can dramatically influence the rates and distribution of diagenetic reactions in hemipelagic deep sea sediments. Obviously, many of the physical, chemical, and biological processes in the deep sea are becoming known well enough to model quantitatively; deep sea oceanography has largely passed beyond the stage of simple descriptive work. Major advances are likely to come in the near future from scientists who are able to creatively incorporate their