"Research on problem solving, using the Tower of Hanoi puzzle as the laboratory task, 1969." The Tower of Hanoi is "a puzzle of Chinese origin involving a pyramid of disks impaled on one of the vertical pegs. The task is to move the pyramid of disks impaled to one of the other pegs, moving only one disk at a time and never placing a disk atop another that is smaller than it. . . . If chess plays the role in cognitive research that Drosophila does in genetics, the Tower of Hanoi is the analogue of *E. coli*, providing another standardized setting around which knowledge can accumulate." [From *Models of My Life*]

crutch afforded by theory even for first steps, and the consequence sometimes seems to be elevated commonsense on a computer. Orthodox economists on the other hand never let go of the crutch. To a European both these failings seem peculiarly American. In America economists, sociologists, and the like call themselves scientists. This is much rarer in Europe. The name matters because it signals an intellectual attitude—in particular that in due course theory and facts will be as transparent as they are in physics and yield similar certainties. I have considerable doubts, more or less for the same reasons as Simon gives for his theory: the order of complexity is too high. Social "scientists" for a long time will have to be "boundedly scientific." The claim to be scientists leads many orthodox economists to attempt to fit quite foolish models to data—their substitute for the "scientific" experiment—while it leads Simon to miss the intellectual possibilities of "wrong" theories. Sometimes it also leads him to a quite shallow "scientism" (see p. 190).

This is an autobiography, and we learn something about Simon the man. He is evidently widely read, a great linguist, a workaholic, and very decent. There are fascinating accounts of university politics, of the first tentative steps to artificial intelligence, of his experiences at the Cowles Foundation, and of his travels. He has thought very widely over many areas, and his contributions are clearly important. For my taste he takes too much pride in "gongs"—that is, signs of external recognition, from election to the National Academy of Sciences (as first social scientist) to the Nobel Prize. Of course it is perfectly natural to feel pride, but perhaps it is nicer to keep it to oneself. But this is a small failing.

The judgment I reach at the end of my perusal of the book is that Simon could have been a great scholar but has only been a very good one. That is because he has been somewhat too ready to "satisfice" rather than to strive to reach beyond his grasp.

FRANK HAHN
Faculty of Economics,
Cambridge University,
Cambridge CB3 9DD, United Kingdom

An Alternative to Associationism

The Organization of Learning. C. R. GALLISTEL. MIT Press, Cambridge, MA, 1990. xii, 648 pp., illus. $45. Learning, Development, and Conceptual Change. A Bradford Book.

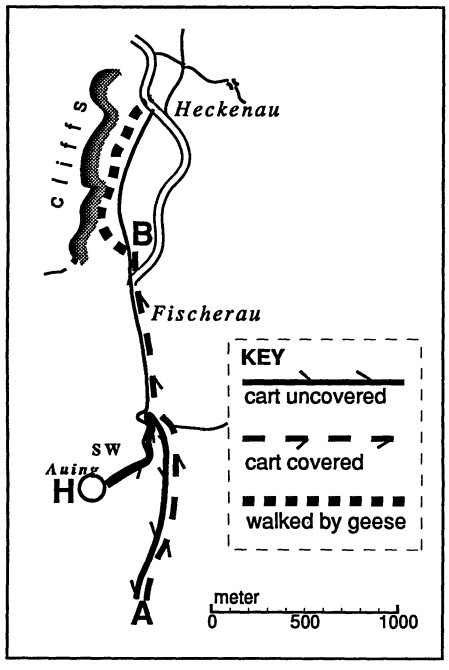
In two books, separated by 10 years, Charles Gallistel has sought to loosen the grip of the British empiricist philosophers on the study of learning by relating learning to the natural history, motivational structure, and neurobiology of particular species. In the first book, *The Organization of Action*, Gallistel brought together a set of important historical papers about the control of behavior that outlined the elementary units of behavior—reflexes, servomechanisms, and oscillators. He then considered the rules of interaction for these units and their organization into larger hierarchical control structures. In essence the first book provided information about how organisms function as a prerequisite to a realistic theory of behavior and learning.

In the present book Gallistel makes more explicit his alternative framework for the study of learning. He specifically rejects the basic assumption of associative theory that temporal contiguity between events is a necessary and sufficient determinant of learning. He replaces it with computed correlations of events in time stemming from a representational conception of learning based on complex functional isomorphisms between the environment and neurophysiological mechanisms. In this approach, the animal is assumed to record the position and timing of each environmental event veridically; thus, changes in behavior with experience are assumed to reflect changes in the statistical certainty of event correlations rather than changes in the strength of associations and their neural basis. In chapters on operant conditioning (based on expected overall rates of reward) and Pavlovian conditioning (based on stimulus correlations in time) he reviews the well-recognized difficulties with unidimensional associative accounts that explain learning by the simple pairing of a single stimulus (or response) with reward.

Though the sound of "computational," "representational," and "isomorphic" strung together in a single sentence may delight avid followers of cognitive science and send behaviorally oriented researchers scrambling for the exits, Gallistel is fairly cautious about how he uses these terms. "Computational" simply means computable; "representational" means there is a relatively rich adaptive correspondence (isomorphism) between the encoding process (the way the brain operates) and the processes and stimulus relations in the external environment.

Admittedly, the idea of a functional isomorphism between the environment and its internal representation is not new, nor does it entail Gallistel's conceptual approach. For example, traditional learning theorists have viewed the result of operations such as response-contingent reward as isomorphic with physiological changes in connections between neurons. Also, there are points in the book when Gallistel seems to use the concept of isomorphism to invoke a primitive realism (things in the environment must correspond to things in the head). Still, his particular implementation of a richer correspondence between environment and mechanism is a welcome alternative to traditional attempts to compress the complex determinants of learned behavior into the strength of a single associative bond, or even more recent efforts involving multiple associative bonds.

This is an ambitious work, neither glib nor superficial. The book has enough detail



Example of a two-leg experiment on dead reckoning. "Two domestic geese were transported in the open cage from *H* to *A*. At *A*, the cage was covered completely and the geese were further transported to *B*, where they were released. The two geese walked together and stopped at the indicated spot. The course they took was appropriate for the uncovered leg of the cart-trip. Had they been released at *A*, this course would have carried them near home." [From *The Organization of Learning*; based on U. V. Saint Paul, in *Avian Navigation*, F. Papi and H. G. Wallrap, Eds. (Springer-Verlag, 1982)]

to interest experts and sufficient examples and graphics to encourage the more general reader through the sometimes long sections on modeling and isomorphisms. This is one of the increasing number of books that would be well served by publication with a diskette or CD-ROM of simulations and models.

In the book's opening chapter Gallistel strikes a distinctly ecological note in a series of vignettes illustrating how learning modifies the everyday behavior of animals—ants ably returning home with booty over featureless desert sands, bees coming on time to share breakfast on the terrace with a naturalist. Accounting for these examples ultimately reveals his attempt to construct a complete picture of how animals represent stimulus events.

Gallistel's inclusive picture of learning begins with how representation fits into the mechanisms by which animals locate themselves efficiently and accurately in space and time, including the phenomena of navigation, dead-reckoning, cognitive maps, and circadian and interval-based times of occurrence. Gallistel then considers the encoding of events by counting and estimates of rate and the representation of the correlation of multiple events in time in Pavlovian conditioning. He completes his picture with consideration of how information may be encoded and retrieved from the nervous system. Throughout the book Gallistel focuses on the representation of information in vectors and proposes a number of models of the phenomena he recounts.

The literature reviewed, though not exhaustive, is surprisingly diverse, ranging among the topics of natural history, physiological ecology, ethology, human information processing, animal learning, and neuroscience. There is considerable focus on basic data, and Gallistel does not avoid making value judgments and arguments criticizing and extending other people's work. Because an entire book could have been written on any one of the major topic areas, residents of each area are bound to find shortcomings. I certainly found the sections on Pavlovian conditioning highly selective, and a few accounts of data did not quite jibe with my interpretations. The sudden introduction of a location sense in chapter 6 and the distinction between proximal and distal cues were confusing. There are several points at which I wasn't compelled by the contrast Gallistel saw between hypotheses. For example, I struggled with the purported differences between the expectancy and the entrainment models of how events are located in time; the section reminded me of the interesting but apparently indefinable differences between expectancy and stimulus-response learning theorists in the 1940s.

I found the initial chapter on representation difficult and the chapters on number and rate too idiosyncratic. The rate chapter in particular appears to confuse paradigms in which the probability of payoff for different alternatives changes over time (for example, concurrent variable-interval schedules of food presentation) with those in which the probability remains constant (for example, concurrent fixed-ratio schedules or probability-learning procedures). It doesn't seem plausible that a matching of responding to reinforcement rate should occur in both circumstances through the same mechanism. Also, sensitivity to rate transitions would seem to be an important determinant of switching between alternatives.

But on the whole I was struck by the useful and entertaining way in which much of the experimental material is reviewed, making this a reasonable introduction to several research areas. Gallistel does not shy away from taking sides, and I liked many of his observations (for example, his demonstration that consistent numerical constants in the Rescorla-Wagner equations cannot predict the range of phenomena apparently accounted for at a qualitative level, or his expression of doubts about attempts to build a cellular alphabet of learning types). The modeling enterprise is usually interesting, though often of a work-in-progress nature. There is perhaps too much argument concerning vector representations and isomorphisms given our current data, but these are Gallistel's central points and 20 years' hindsight may reveal brilliance.

In the end what I missed most is an account of how these representations, computations, and isomorphisms come together to produce (to compute, if you will), say, a foraging rat. Though learning is viewed complexly in this book, it is still defined in static terms as the accumulation of information about the world, rather than as a dynamic component of the motivational processes and mechanisms coadapting the animal and the environment. This contrast can be highlighted by comparing the language and procedures of the chapters on Pavlovian conditioning with those of the earlier analyses of how animals function in their individual worlds.

Put another way, Gallistel's two books need to be fitted together more explicitly. The organization of action and the organization of learning coevolved. In this respect, Gallistel's two books are best appreciated as a thought-provoking and information-filled prolegomenon, a marked advance toward embedding the study of learning in the context of an evolved functioning organism (see W. Timberlake and G. A. Lucas, "Behavior systems and learning: from misbehavior to general laws," in *Contemporary Learning Theories*, S. B. Klein and R. R. Mowrer, Eds. [Erlbaum, Hillsdale, NJ, 1989], pp. 237–275). Scientists broadly interested in the fit of learning and behavior could not pick a better starting place to continue the task of integration.

WILLIAM TIMBERLAKE
Department of Psychology,
Indiana University,
Bloomington, IN 47401

Language Without Cognition

Laura. A Case for the Modularity of Language. JENI E. YAMADA. MIT Press, Cambridge, MA, 1991. xviii, 169 pp., illus. $27.50. Issues in the Biology of Language and Cognition. A Bradford Book.

Is human language a separate faculty, or is it just one of the mightier weapons in our general cognitive armamentarium? Are complex vocabulary and syntax our crowning intellectual achievement, evidence of ab-