a goal function. For animals, the utility or cost of a particular behavior is defined by its contribution to the animal's fitness, that is, the animal's subsequent survival and reproductive success. McFarland and Bösser argue that for robots, on the other hand, these notions should be defined in terms of the robot's commercial success in the marketplace. For example, in order to proliferate, a dishwashing robot must successfully compete with human dishwashers and existing automatic dishwashers in terms of cost, reliability, and quality of work. The book goes on to develop this similarity between commercial success and reproductive success into a formal analogy. Along the way, a number of other issues, such as the roles of motivation, goals, and learning in animals and robots, are also discussed.

A highlight of the book is a detailed illustration of the application of this general economic framework to the overall design of a housekeeping robot. Here the authors assume that a particular behavioral repertoire is given (for example, collecting dishes, mopping the floor, and so on) and the essential problem is to optimally deploy these behaviors in time while simultaneously considering issues of stability, reliability, and customer appeal. In general, the book tends to treat behaviors at a fairly high level, abstracting from details of the underlying mechanisms. In addition, the problem of selecting from a set of mutually incompatible alternatives is emphasized over the problem of fine-tuning ongoing behavior, though both are presumably crucial to an agent's success. Nevertheless, this simple example does clearly demonstrate the kind of analysis that the economic framework for intelligent behavior makes possible and illustrates how the results of such analysis can be used to guide the overall design of an autonomous robot.

Indeed, this book is at its best when drawing out the many strong analogies between animal and robot behavior and when presenting and illustrating the economic framework that is its central contribution. However, I think the book would have benefited from a clearer outline of its principal goals and overall plan at the outset. As it stands, the reader is left to sort through a number of seemingly tangential discussions and sometimes confusing terminology in order to grasp the essential ideas, a situation that the overly long lists of "points to remember" that end each chapter do little to alleviate. In addition, the minimal discussion of the large body of existing work on computer simulations of adaptive behavior and biologically inspired robotics is inadequate for this book to serve as a general introduction to the study of autonomous agents. Nevertheless, *Intelligent Behavior in Animals and Robots* stands as an important first attempt at laying the groundwork for a unified treatment of the behavior of animals and robots. It sets the standard against which any future discussion of these issues must be judged.

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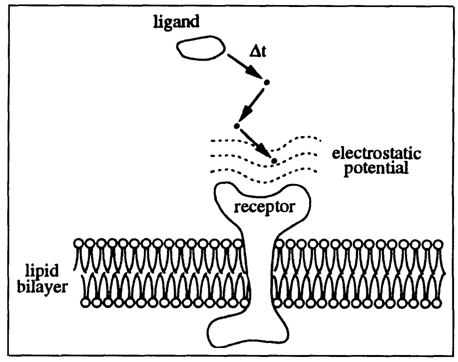
Quantitative Cell Biology

Receptors. Models for Binding, Trafficking, and Signaling. DOUGLAS A. LAUFFENBURGER and JENNIFER J. LINDERMAN. Oxford University Press, New York, 1993. x, 365 pp., illus. $69.95 or £50.

Curare, used for centuries by the Indians of the Amazon basin as an arrow poison, was brought to England by Sir Walter Raleigh in the 16th century. Claude Bernard began a systematic investigation of its action in 1850. But it was J. N. Langley, examining the antagonistic effect of curare on nicotine stimulation of skeletal muscle nearly a century ago, who concluded: "Since neither curare nor nicotine, even in large doses, prevents direct stimulation of muscle from causing contraction, it is obvious that the muscle substance which combines with nicotine or curare is not identical with the substance which contracts. It is convenient to have a term for the specially excitable constituent, and I have called it the receptive substance. It receives the stimulus, and by transmitting it, causes contraction" (*Proc. R. Soc. London Ser. B* **78**, 170 [1906]). These two principles—the recognition capacity for specific ligands and the subsequent ability of the ligand–receptor complex to initiate a biological response—form the basis of our current understanding of receptor biology. In fact, the role of ligand–receptor interactions in fundamental cellular functions is one of the central themes in biology today, from bacterial chemotaxis to the mechanisms of the new anti-thrombotic agents.

The development of theoretical models of ligand–receptor interactions and their mathematical basis was initiated by A. J. Clark in 1926. Few of the basic principles have changed, but over time increased understanding has added complexity. Fortunately for those working in this area, Lauffenburger and Linderman's *Receptors: Models for Binding, Trafficking, and Signaling* draws on mathematical and cellular bioengineering concepts to lay a detailed foundation in three of the major conceptual areas of receptor biology: (i) cell-surface receptor–ligand binding fundamentals, (ii) receptor–ligand trafficking, and (iii) signal transduction. The extraordinary rapidity of the pace of research in all three areas, but especially signal transduction, necessarily has restricted the contents of the book to specific examples. The authors have chosen wisely. In a section on receptor–ligand trafficking they thoroughly dissect the intracellular itinerary of the epidermal growth factor receptor. The emphasis is on mathematical modeling and the theoretical and practical evaluation of biological data. For those who are not mathematically fluent, the models may be overly detailed. Yet the biological overviews provide an adequate context for them. Surprisingly, neurobiologically important ligands and receptors, such as the excitotoxic agents—which are currently generating tremendous excitement in the field of receptor biology—are not mentioned in the book. Despite this omission, given the molecular manipulations now possible for ligands, receptors, and their associated constituents, the conceptual framework in quantitative cellular biology provided here is a welcome one.



"Brownian dynamics calculations for the movement of a ligand. The position of the ligand after a time step of Δt is determined by its previous position, the influence of deterministic electrostatic forces, and the random thermal displacement." [From *Receptors*]

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Books Received

Ancient American Inscriptions. Plow Marks or History? William R. McGlone *et al.* Early Sites Research Society, Sutton, MA, 1993. xvi, 415 pp., illus. Paper, $19.95.

Ancient DNA. Recovery and Analysis of Genetic Material from Paleontological, Archaeological, Museum, Medical, and Forensic Specimens. Bernd Herrmann and Suzanne Hummel, Eds. Springer-Verlag, New York, 1993. xii, 263 pp., illus. $69.

Ancient Technologies and Archaeological Materials. Sarah U. Wisseman and Wendell S. Williams,