ants were the subject of his primary research. It is indeed fortunate that he was able to get this book almost completed before his death in 1968. Howard R. Topoff, his last graduate student and the only one to do field research with him, completed the final chapter, wrote captions for illustrations, compiled the bibliography, and did final editing. It is clear that the editing was minimal, and the style of Schneirla's writing has basically remained. This was probably the most practical approach, but it has perpetuated Schneirla's talent for hiding simple concepts and minimal data in abstruse sentences.

The book is written in a "semipopular style," and the reader needs no previous knowledge of ants or social insects. I believe Schneirla went too far in not including descriptions of techniques and accounts of his own experiences. Had the book thus conveyed more of the essence of fieldwork with these insects it would have been more likely to stimulate readers to finish it and go out and find a colony. The account is highly personal, however, in that it emphasizes the research of Schneirla and his immediate associates, citing other work primarily when, as in the case of all the African *Dorylus* species, Schneirla had no direct experience with the ants being discussed. Because Schneirla so dominated the field the book does not suffer heavily by ignoring some of the literature, but readers should be aware that the treatment is not comprehensive. For example, papers by Akre, Haddow *et al.*, Rettenmeyer, Watkins, and Willis published up to 1968 have been omitted, not to mention literature since that date.

Schneirla was the first to demonstrate that army ants have a functional cycle composed of alternating nomadic and statary phases. During the nomadic phase colonies have a brood of larvae that usually develop into worker ants, and the colonies emigrate nightly for about two weeks. When the larvae spin cocoons, the colony enters the statary phase, in which it stays in one site for about three weeks and a new brood of eggs is laid. The next nomadic phase is started when the one brood emerges as young adults and the second brood is eggs and young larvae. Schneirla has assembled a mass of convincing data indicating that stimulation from the broods is the primary factor influencing the alternating nomadic-statary cycles. The physiological cycle of the queen is an integral part of the functional cycle of the colony. She becomes gravid periodically, about once a month, and lays up to 300,000 eggs in about eight days.

This nomadic-statary functional cycle is most precise and consistent in *Eciton hamatum*, the species which Schneirla studied first and on which his description of the cycle is primarily based. This is one of the two most epigaeic or surface-adapted of the 140 or so species of army ants in this hemisphere. Most of the species of *Eciton* and the other genera of army ants are largely or completely subterranean. Therefore the book gives a distorted impression of how most army ant species behave.

Schneirla also proposed (contrary to the prevailing view before his research) that lack of food in the vicinity of the nest is not the main or proximate stimulus for emigration. His most recent work with *Aenictus* in the Philippines demonstrated that the emergence of a new brood of adult workers is not adequate to initiate a new nomadic phase. Furthermore, the multiple emigrations within a single day are attributed in part to the fact that lack of food causes larvae to stimulate greater activity among workers.

The main weakness of Schneirla's approach is his tendency to overgeneralize, emphasizing similarities within and among the different genera and species while sometimes omitting conflicting data. Schneirla was an outstanding observer of insect behavior in the field but did not conduct carefully controlled experiments to back up his hypotheses. This is partly due to the difficulty of keeping army ants successfully in the laboratory for long periods. Schneirla did perform numerous "tests" in the field and laboratory, but the exact methods used and quantitative results are almost universally absent from his publications. In this book phrases such as "observations and tests show" frequently precede conclusions enforcing his brood-stimulative theory. Although I do not question the soundness of most of the conclusions, they would be more convincing if supporting data were provided.

The role of pheromones in the entire functional cycle was recognized as important by Schneirla, but almost nothing is known about their source and role in this group of ants. It also seems likely that circadian rhythms play some role in the pronounced nocturnal-diurnal activities shown by some species, but the book makes no mention of them.

There is an extensive literature on the ant-birds and arthropod ant-guests or inquilines associated with army ants. Most of this literature is ignored in the book, and where guests are mentioned incorrect information and misleading statements predominate.

The book has some excellent photographs, including 13 in color, chosen by Schneirla, but it is unfortunate that all the color plates are reprinted in the text in black and white when supplementary and better photographs could have been used instead. It is also a mystery why an out-of-focus picture of a bivouac is used for a full-page color plate and an unnatural drawing of a dead ant is placed on the cover.

In spite of its shortcomings, the book is essential for anyone seriously studying the evolution of social behavior in insects. The army ants are perhaps the best example of group action and interdependence in insect colonies. Anyone publishing on army ants must be greatly indebted to and dependent upon the tremendous volume of data which Schneirla assembled in his lifetime. This book is a guide to those data, including some heretofore unpublished observations and a summary of numerous papers. It is a prime source of what is known and a stockpile of ideas for future research.

CARL W. RETTENMEYER
Biological Sciences Group,
University of Connecticut, Storrs

Regulatory Agent

Cyclic AMP. G. ALAN ROBISON, REGINALD W. BUTCHER, and EARL W. SUTHERLAND. With contributions by Th. Posternak and Joel G. Hardman. Academic Press, New York, 1971. xii, 532 pp., illus. $17.50.

Cyclic AMP (adenosine 3′,5′-monophosphate) was discovered in 1957 in the course of a study of the mechanism by which two hormones, glucagon and epinephrine, cause the breakdown of glycogen in mammalian liver. Since that time it has been shown to mediate the actions of a wide variety of hormones and other environmental stimuli. The number and diversity of biological processes for which there is good evidence of cyclic AMP involvement continue to grow rapidly. The nature of the involvement of cyclic AMP in various biological systems suggests the generalization that cyclic AMP is a regulatory agent

of paramount importance throughout the animal kingdom as well as in microorganisms, and one which appeared very early in the course of evolution. As animal cells became progressively more complex and specialized, they appear to have retained this basic regulatory system to control the rate of their activities. Thus in the course of evolution new types of specialized cells, rather than abandoning the cyclic AMP system for the regulation of their activity, developed a specialized sensitivity so that only very special types of chemical substances would be able to stimulate the synthesis of cyclic AMP in them and by this means trigger them into the performance of their specialized functions. Viewed within this framework, the natural occurrence and physiological effectiveness of cyclic AMP in a wide variety of dissimilar tissues become more readily comprehensible. It is just this diversity of processes in which cyclic AMP is involved that has puzzled many biologists and, ironically, delayed general acceptance of the importance of this molecule.

The book under review was written by members of the laboratory in which cyclic AMP was discovered. The book ranges over the entire field of cyclic nucleotide research and surveys most of the literature available at the time of writing. It contains particularly thorough accounts of the role of cyclic AMP in mediating the actions of catecholamines, in regulating carbohydrate and fat metabolism, and in controlling steroidogenesis. Other sections provide a discussion of the enzymes that catalyze the synthesis and destruction of cyclic AMP, a survey of the numerous hormones in whose actions cyclic AMP has been implicated, and a review of knowledge concerning the role of cyclic AMP in lower organisms. There are, in addition, three special chapters by individual authors: a fascinating historical account by Sutherland of the developments that led to the discovery of cyclic AMP; a description by Posternak of the chemical properties of the cyclic nucleotides and of laboratory methods for the preparation of cyclic AMP and various analogues; and a lucid chapter by Hardman on the biology of guanosine 3′,5′-monophosphate, a substance closely related to cyclic AMP and one that has attracted the attention of an increasing number of investigators within the past few years because of its possible importance as another intracellular regulatory agent.

Until about two years ago, one of the most important factors limiting research in this field was the enormous complexity of the methods available for assaying cyclic AMP. In an appendix, the authors describe the very complicated system used in their laboratory. The amount and brilliance of the research that has come from that laboratory are all the more impressive in view of the cumbersomeness of the methodology utilized until recently.

Scientists who have been working in this field will find the book useful as a well-written reference text. In addition, it should prove valuable as an introductory text to the many hundreds of scientists who have recently become interested in the cyclic nucleotides. One of the more valuable aspects of the book, for established as well as for new workers in the field, is the insight it provides into the thinking of a laboratory which has figured so prominently in this field since its genesis some 15 years ago.

PAUL GREENGARD
Department of Pharmacology,
Yale University School of Medicine,
New Haven, Connecticut

Pharmacological Tool

6-Hydroxydopamine and Catecholamine Neurons. A symposium, Bürgenstock, Switzerland, Oct. 1970. T. MALMFORS and H. THOENEN, Eds. North-Holland, Amsterdam, and Elsevier, New York, 1971. 368 pp., illus. $22.50.

At a Pharmacology Society meeting recently one of the contributors to this volume introduced his paper with the remark, "I second the nomination of 6-hydroxydopamine as the drug of the year." If anything, he understated the case, for it is possible that no compound since reserpine has proved so useful a tool in the investigation of catecholamine-containing neurons.

The drug (known as 6-OH-DA) produces what has been termed a "chemical sympathectomy" in vertebrates; but variations in experimental conditions and species have resulted in confusion and contradictions in the literature about its effects. This book is a collection of papers presented at a closed symposium sponsored by F. Hoffmann-La Roche and Company for the purpose of clarifying the mechanism or mechanisms of action and organizing current knowledge of this research tool for publication. The editors wisely selected a multidisciplinary group of contributors to integrate the morphological, biochemical, and pharmacological aspects of the tribulations of catecholamine neurons subjected to 6-OH-DA.

The mechanism of action of 6-OH-DA is dependent upon relatively selective uptake into catecholamine neurons, depletion of amine, incorporation of the drug into granular synaptic vesicles, and, after higher doses, degenerative changes due to formation of toxic oxidation products in the neuronal cytoplasm. Peripheral adrenergic neurons are affected in a dose-dependent manner, their terminal axons (varicosities) appearing most susceptible and the cell bodies most resistant.

The drug produces either of two conditions, which are distinguishable only by electron microscopy during the first few days after dosing: (i) changes compatible with early degeneration, even in the cell body, with prompt reversion to normal appearance, or (ii) complete degeneration of the nerve terminals, which is reversible only if the cell body is not destroyed, and even then slowly.

Because 6-OH-DA does not cross the blood-brain barrier in the animals studied, it has been injected intraventricularly or intracisternally, and affects those norepinephrine- or dopamine-containing nerve cell bodies or terminals which receive the highest concentration of the drug. Intracerebral injection under stereotactic control is described by Ungerstedt as a precise and selective method of mapping catecholamine neuronal pathways in the brain. As in the peripheral neuron, the distinction between reversible and irreversible changes is difficult, and, as Bloom points out, even cell bodies which appear heavily damaged several weeks after injection may still be viable.

The book is divided into sections dealing respectively with (i) peripheral neurons, (ii) central neurons, (iii) effects on adrenergic function, and (iv) mechanism of action, and a fifth section containing papers which must have seemed inappropriate for inclusion in any of the other four. Several of the papers are abundantly illustrated with fluorescence or electron micrographs. The fluorescence micrographs are generally quite good; a few of the electron micrographs are technically imperfect (probably because they represent early work of the investigators—this reviewer pleads guilty to similar faults) or are of too low a magnification to permit easy interpretation. At the end of the