Book Reviews

The Universal Constructor

Theory of Self-Reproducing Automata. JOHN VON NEUMANN. Edited by ARTHUR W. BURKS. University of Illinois Press, Urbana, 1966. 408 pp., illus. $10.

The scientific community is indebted to Arthur W. Burks for completing this unfinished work of the late John von Neumann. An immense effort must have gone into the collection of the fragmentary manuscripts, obtaining information from friends and co-workers of von Neumann, and completing the project without doing violence to the intentions of the author.

The volume begins with an editor's introduction, which consists of a very interesting discussion of the contributions von Neumann made to the development of modern computers. Part 1 consists of a series of lectures which were delivered at the University of Illinois in 1949 and which are now somewhat dated. But part 2 contains a complete design for an automaton that can reproduce itself, and it is this part that makes the volume a significant contribution to the scientific literature. I shall restrict my comments to this part.

The theory of computers must be traced back to a fundamental result by A. M. Turing, 30 years ago, establishing the possibility of a computer that is "universal." Such a computer, given appropriate instructions, can do anything any computer can do. Von Neumann wished to prove a companion result, to show that there exist universal construction automata. Indeed, the book concludes by showing the existence of an automaton that is a universal computer, a universal constructor, and able to reproduce itself.

For simplicity the model of the automaton is constructed in two dimensions. It is assumed that the plane is divided into square cells, all of which are alike. Each cell can be in one of 29 states, and construction is accomplished by changing the states of remote cells. A self-reproducing automaton imbedded in inert surroundings will through a long sequence of steps change the surroundings until a copy of itself exists at a remote location.

Sixteen of the states are used for transmission of information. They can be hooked up to build lines through which information travels in any desired direction. They transmit two types of signals, one of which is for ordinary transmission and the other is used to "kill," that is, to return a state to its inert status. Four states do most of the work, containing the logic of the system. Eight states may be viewed as embryonic, transitional states in the changing of an inert cell to an active one. And the 29th state is the inert one. The process has a discrete time-structure built into it. The state of any cell in the next moment is determined by its own state at the present, and by the state of its four neighboring cells. That is all the machinery that von Neumann requires.

He first shows how, with ingenuity, a wide variety of specialized organs may be built of these simple cells. Then he uses the components to build his universal automaton. The latter consists of three major parts. One is the construction unit (CU), which uses information supplied by its memory to construct a remote automaton. This is quite similar to a universal Turing machine. Indeed it can be constructed so that it also serves as a universal computer. The second part is the memory control unit (MC), which extracts information from the memory and changes this information. The memory itself is contained in a linear array (L), in a simple code. The array is manipulated by extendable arms under the control of MC.

The basic idea is really very simple: A universal construction automaton is designed to follow instructions, coded in its memory, to construct an automaton. It also has the ability to copy its own instructions. When such a unit is given *its own* description, it will copy itself together with these instructions, and will thus have reproduced itself. If the newly born automaton is then sent a starting signal, it will in turn reproduce itself. While this is a simple and ingenious idea, its complete implementation is a monumental task.

Burks deserves credit for the editing of a manuscript that was often no more than a sketch, for the correction of various minor errors, and for the completion of the design of the self-reproducing automaton. He has carefully preserved as much of the original manuscript as possible, and sections written by him are specially marked. Indeed, my one criticism is that the editor has sacrificed readability for historical accuracy.

An interesting philosophical question may be raised in connection with the model constructed. It is capable of parallel processing in the strongest sense—that is, a change may occur in every cell at every moment. Yet only a minute fraction of this capability is used in the construction, just as our computers do parallel processing only in a most trivial sense. Wouldn't a computer all of whose memory cells could be changed simultaneously be a vastly more powerful tool than our present machines? And does this furnish a clue to why the human mind is so incredibly efficient compared with computers?

JOHN G. KEMENY
Department of Mathematics,
Dartmouth College,
Hanover, New Hampshire

Molecules and Bulk Properties

Statistical Physics. GREGORY H. WANNIER. Wiley, New York, 1966. 544 pp., illus. $11.50.

In the hundred-odd years since its founding, the branch of physics which explains the properties and behavior of bulk matter through statistical properties of large numbers of molecules has been called by many different names, each of which emphasizes a particular aspect of the field. To Clausius it was the kinetic theory of heat. To Gibbs it was statistical mechanics. To Guggenheim it was statistical thermodynamics. Clausius' name reflects the preoccupation of the middle 19th century with heat engines. That of Gibbs reflects the late-19th-century point of view that any completely satisfactory physical theory must be a branch of analytical dynamics, while Guggenheim's emphasizes the calculation of equilibrium thermodynamic properties from properties of molecules.

The name statistical physics chosen by Gregory Wannier for the title of his first-year graduate textbook felicitously describes a field which in spite of its venerable age is growing and is solving new and significant problems and whose concepts and methods enter into almost every active branch of the physical sciences.

The tone of the book is pragmatic. It neither ignores nor is bogged down in the question of the provenance of the fundamental distribution in phase space. It combines without apology ideas that have their source in phenomenological thermodynamics with ideas arising from the atomic-molecular picture of matter. It is mathematically sophisticated but the ratio of formulas to text is low. The reader encounters physical concepts such as "doped semiconductors," "Brownian motion," or "Joule-Thompson effect," at least as often as mathematical ones such as "Mayer diagrams," "Wiener-Khinchine theorem," or "Fermion operator."

Part 1 of the book, Principles of Statistical Thermodynamics, is a kind of fugue on the themes of phenomenological thermodynamics in its classical axiomatic form, on the one hand, and statistical and dynamical concepts on the other. The topics covered constitute the foundation material for both a classical course in thermodynamics and one in statistical mechanics. As the author points out in the preface, this combination permits a mutual illumination of concepts as well as an economy of presentation. Part 2 presents what must be considered to be the meat of any course in statistical physics, the application of principles to the explanation of specific physical phenomena. The choice of examples is eclectic, reference being made to such topics as law of mass action, the theory of the imperfect gas, osmotic pressure, and phase rule, which belong to the discipline of chemistry, as well as ferromagnetism, electrons, metals, and normal mode frequency spectra of crystals, well within the bailiwick of physics. A noteworthy pedagogical tour de force is the presentation of the Onsager solution of the two-dimensional Ising model of ferromagnetism (in the form given by Schultz, Mattis, and Lieb) in the space of nine pages. Part 3 of the book presents a very good introduction to the statistical theory of time-dependent phenomena in the same spirit as the previous sections. Such fundamental matters as the paradoxes of irreversibility and correlation formulas for transport properties are discussed, as well as such practical topics as the Wiedemann-Franz law, solution of the Boltzmann equation, Hall effect, and mean free path.

This is an important new textbook in the field of statistical physics, first because of the pedagogical skill with which it is written, but more significantly because it breaks down the traditional but now irrelevant barriers between the phenomenological and the particulate view of matter, between the disciplines of physics and chemistry, and between equilibrium theory and kinetic theory.

MELVILLE S. GREEN
Statistical Physics Section,
National Bureau of Standards,
Gaithersburg, Maryland

Primate Study

Lemur Behavior. A Madagascar Field Study. ALISON JOLLY. University of Chicago Press, Chicago, 1967. 201 pp., illus. $6.95.

It is unusual in Madagascar to find an environment that is still in its natural state. Almost everywhere the ecologist arrives late, after the destroyers of forests, the hunters, and the scientific collectors. There are, however, a few places where it is still possible to make an interesting study of normal animal populations. Among them is the reserve of Monsieur de Heaulme at Fort-Dauphin, in the south of the island. It was under the good conditions there that Alison Jolly did the essential part of the excellent work that is reported in *Lemur Behavior.*

It is sometimes difficult for a foreigner to be completely accepted in a strange country in a short time. It is rather a tour de force that Jolly accomplished this during her stay in Madagascar. Her natural charm conquered the Malagasy and the French who knew her, and I am glad to report that her sojourn in Madagascar left a very good memory everywhere and that it is cited as an example to be imitated.

Her work itself is also, in my opinion, exemplary, for her study is of the most intelligent, and the least easy, kind that can be made in Madagascar. She did not collect specimens for museums, nor did she destroy the animals she studied. Instead, she patiently observed their life and attempted to understand it.

The results of this work are set forth in a well-arranged book that includes numerous photographs, maps, and convenient tables. In an introductory chapter Jolly summarizes the different kinds of lemuroids and gives a sketch of the literature that has been devoted to them, from the early descriptions by the Sieur de Flacourt through the most recent studies. This introduction will be particularly useful to American readers who are not proficient in French. Jolly then gives more detailed information about the main subjects of her study, *Propithecus verreauxi* and *Lemur catta,* their habitat, and the manner in which the study was carried out.

Chapter 2 is devoted to *Propithecus verreauxi verreauxi,* its description, ecology, and behavior and its relations with other species, particularly *Lemur catta,* and with other *P. v. verreauxi,* adults and juveniles. The characteristics of this propithecine are generally similar to those of western subspecies, but they deserve this thorough study. Chapter 3, similarly arranged, deals with *Lemur catta.* It gives a fairly complete account of this species, which, although very common in zoological gardens, has not previously been observed in detail in nature and which seems in many respects original and different from other species of lemurs. In chapter 4 *Lemur catta* is compared with another *Lemur, L. macaco collaris,* which lives at the edge of the area inhabited by *L. catta.*

In chapter 5 all types of communication—olfactory, tactile, visual, and auditory—are summarized and their motivation and function interpreted. Chapter 6 is devoted to territory and its importance for the species. All social lemuroids have well-defined territories. Comparisons with what is known of other primates from the most recent field studies of Haddow, Jay, Schaller, Southwick, and others are very instructive and lead to some interesting reflections on the evolution of the lemuroids.

The last chapter, on the evolution of social behavior in the primates, also permits enlightening comparisons between the social behavior (aggression, encounters between the sexes, relations between the young) of lemuroids and that of other primates.

The interest of Jolly's work lies in its giving a more complete knowledge of the life under natural conditions of two types of primates that are as yet very little known. Departing from her very specialized study of two species, Jolly enlarges her conclusions to the lemuroids as a whole, drawing on personal observations made in different parts of Madagascar and on the litera-