cytologist might wish for more than five pages; the student of behaviour might wish for a fuller treatment of the nest building, migration, sense of direction (although this does include a reference to recent work on the possible part played by Corioli's force in this phenomenon), social organization, establishment of territory, etc.; and the morphologist for a fuller indication of the great variability exhibited by the main anterior arteries and so on. When one considers how any of these sections could be expanded without enlarging the volume, one is faced with the problem of what could be omitted. Such a consideration brings a realization of the excellent balance between the breadth of outlook and the great amount of detail contained within the book, and in spite of this it is so clear in exposition that it is easy to read.

There are a few slips such as "co do-mésoblaste" instead of cordo-mésoblaste in the legend of Fig. 353 on p. 488. Other mistakes were noted in reading; but it was later found that these and others were corrected in a list of errata on p. 1154. Each chapter is provided with a select and useful bibliography, and the volume has at the end a detailed table of contents and a full index so that reference to any subject is easy. Unfortunately, the publication of the series is falling somewhat behind the announced dates, which is perhaps only to be expected in such a large undertaking at the present time. The editor and publisher alike are to be congratulated on the production of another most worthy addition to the text-books of general zoology. CHAS. H. O'DONOGHUE

MECHANIZATION OF MATHEMATICS

Calculating Instruments and Machines

By Prof. Douglas R. Hartree. Pp. ix+138. (Urbana, Ill.: University of Iillinois Press; London: Cambridge University Press, 1949.) 21*s*.

THE almost exponential rise in the output of scientific and technical research which has been such a marked feature of the past few decades has presented many mathematical problems the solution of which is not possible by known formal methods. The result has been on one hand the development of approximate methods of solution, of which Southwell's 'relaxation' method is an outstanding example, and on the other hand the development of instruments and machines which can carry out speedily and mechanically the complicated mathematical operations involved. The present book, by one who has played a leading part in the utilization of instruments and machines, and in encouraging their development, provides a very welcome addition to the literature of the subject. It is well produced, well illustrated by photographs and diagrams, and contains at the end a list of 122 references.

The book is based on a course of lectures given by the author, so that he has concentrated on those aspects of the subject which interest him most, and on those instruments and machines with which he is most familiar. This has led to the exclusion of reference to devices limited to the solution of a particular problem or equation, and attention is devoted entirely to 'physiology'—what a machine can do and how it can be made to do it—and not to 'anatomy'; although occasional reference is made to components ('hardware') out of which machines are constructed. It is to the user, rather than the designer, that this book will mainly appeal.

The distinction which the author makes between instruments and machines is that which the Americans denote by the adjectives 'analog' and 'digital'. In the former, numbers are represented by some physical quantity; elementary examples are graph paper and the slide rule; but the section of the book devoted to instruments deals almost exclusively with the differential analyser. Machines deal directly with numbers: the human hand and the abacus are primitive forms, but the author is here concerned with the various automatic high-speed digital machines in use or under construction in Great Britain or in the United States. For each class fundamental principles have long been known. Kelvin realized how coupled mechanical integrators could solve differential equations, while Babbage's 'analytical engine' was designed to perform the same kinds of operation as the modern machines. It is to advances in mechanical and electrical engineering, and to increased demand, that modern progress is mainly to be attributed.

Mechanization is no substitute for intelligence. As Lady Lovelace remarked in her account of Babbage's plans, these machines can do only what we know how to order them to do. Moreover, they each have their own idiosyncrasies, their special aptitudes, and their limitations. To take full advantage of the special aptitudes, and to avoid the limitations, may call for considerable ingenuity. The new machines demand a new mathematics—or at least a new approach to mathematical problems—in a word, the cultivation of a 'machine's-eye-view'. This means an analysis of the calculation into a sequence of steps within the capabilities of the machine, or, in some cases, even an alternative formulation of the problem, which allows such an analysis more readily to be made. Instances of this are scattered throughout the text, in connexion with instruments and machines as each is considered, and in the highly suggestive final chapter. The machine's-eye view also means the ability to foresee all the snags.

Although the chapters on the differential analyser show that there have been recent advances both in its design and use, interest to-day is centred rather in the development and use of high-speed automatic digital machines. In the earlier machines of this type emphasis was laid on the reduction of computational labour, and elaborate arithmetical units were built in, such as multiplier-dividers and square-rooters. Experience in use showed a need for much more high-speed storage of both numbers and instructions ('memory'). To-day the tendency seems rather in the direction of quite simple arithmetical units, fundamentally addition units, frequently working in the binary scale, combined with greatly increased storage and control facilities. Multiplication is repeated addition, and the author shows how division can be done by an iterative process involving only addition and multiplication, and that much more complicated calculations can be similarly performed. This lays the emphasis on programming and coding, which take times enormously long compared with those required for the most complicated sequences of arithmetical operations. But programming and coding still seem to need the human brain, training, knowledge, and experience. To keep one of the new machines running at capacity would seem to demand a skilled staff by no means small.

W. G. BICKLEY