practically sterile, because of a fundamental difficulty which has not yet been resolved: their *axiomatique* was not 'operation.' "

The work of Tinbergen is an attempt to test statistically a mechanism of business cycle policy, which has been developed over a period of years by the author and a group of Dutch mathematical economists. The analysis considers an array of twenty-two variables, and nine "international quantities considered as data." The variables are classified under three heads: (1) prices, such as wage rates, cost of living; (2) physical quantities, such as total employment, total output; (3) value figures, such as total wages' bill, value of exports. These variables are related by twenty-two equations which "are partly of a definitional or technical nature and partly the reflection of 'direct causal relationships.' "

The monograph is devoted to a study of problems which can be formulated in terms of the mathematical system. These problems are of four kinds: (1) to determine the movements defined by the variables for a set of historically given initial values; (2) to extrapolate the natural tendencies of the system, all conditions remaining unchanged; (3) to determine the movements after a variation has been imposed in the system by some "given policy"; (4) to find the optimum variation, that is to say, to determine the "best policy."

Tinbergen's study will be of interest to those who wish to view the full complexity of the economics problem and to see one of the most heroic attempts yet made to reduce the interacting variables to a mathematical system.

H. T. DAVIS

Grundlagen und Methoden der Periodenforschung. By Karl Stumpff. Berlin, Springer, 1937. 332 pp.

As the title indicates, this book deals with the basic ideas of determining the periodic properties of functions and sets of points, and the methods of applying these ideas to empirical functions and observed data. The author, well versed in such analysis from his meteorological work, has taken pains to explain the fundamentals of the subject in a thorough and readily understood manner. Then he goes on to explain in some detail how the fundamentals are best applied to empirical functions obtained from a recording instrument or a series of observations of some physical phenomena.

The problem of expressing a given function as a linear combination of a series of arbitrary functions is attacked by the method of least squares. The equations for the coefficients are derived in general, and the simplified formulas for the case of orthogonal function systems are set down for ready reference. Various function systems are then discussed. These consist of circular functions (which lead to Fourier series expansions), Legendre polynomials, Hermitian polynomials, and Laguerre polynomials.

As a first application, the methods are applied to the smoothing and interpolation of a series of observations.

Next, the technically very important case of the harmonic analysis of observations with one and two independent variables is treated, including several practical schemes for carrying out the detailed calculations.

An analysis is made of the possibility and practicability of expressing an empirical function in the form of a spectrum. The properties and methods of calculating the spectrum of a series of observations is presented.

A chapter on the application of statistical methods to the analysis of the periodic properties of empirical functions serves to introduce distribution functions, correlations, and a broader point of view than the preceding analytical method of least squares.

Other analytical methods for period analysis are considered. The Laplace transformation, differential and difference relations, and the method of exhaustions are included.

Finally, a discussion of physical aids to period analysis—including physical concepts such as momentum, resonance, and interference; and mechanical and optical devices—serves to complete the discussion of methods of application to practical problems.

There is collected in this book a sound treatment of the basis of the period analysis of empirical functions together with detailed discussions of methods of applying these in practice.

Anyone engaged in such period analysis or interested in a sound discussion of fundamentals will find this book very useful.

HOWARD EMMONS

The Axiomatic Method in Biology. By J. H. Woodger. Cambridge, University Press, 1937. 10+174 pp.

We have here the first attempt to build a system of biology on the basis of abstract logic. The book will probably be harder reading than the author (reader in biology at the University of London) realizes—save for those few who are versed both in Russell's symbolism and in fundamental biology. Nonetheless, its writing was a task well worth doing, and one which has been done excellently. It discusses biology with precision of statement and reliability of reasoning, and clearly shows the conceptual unity underlying a number of basic branches. It emphasizes the wisdom of R. A. Fisher's remark: "I can imagine no more beneficial change in scientific education than that which would allow each (mathematician and biologist) to appreciate something of the imaginative grandeur of the realms of thought explored by the other."*

In justification of the undertaking, Woodger quotes A. N. Whitehead: "There are an indefinite number of purely abstract sciences, with their laws, their regularities, and their complexities or theorems—all as yet undeveloped." And in the preface, which calls the book an experiment, he says: "In every growing science there is always a comparatively stable, tidy, clear part, and a growing, untidy, confused part. I conceive the business of theoretical science to be to extend the realm of the tidy and systematic by the application of the methods of the exact or formal sciences, i.e. pure mathematics and logistic."

Almost the whole substance of the book is given in the symbolic statement of axioms, definitions, and theorems. As a concession to the laity, most statements are also explained, more at length, in words. Some 250 symbols are used, mainly taken from the *Principia Mathematica* or introduced for their biological usefulness; the list of these symbols constitutes, in fact, the only index.

The ten undefined signs can be interpreted as "part of," "before in time," "organized unities," "related by a succession of divisions and fusions," "cell," "male," "female," "whole organisms," "environment," "genetic properties." The most important derived concept is that of a "hierarchy," a relation (xRy) which is one-many and asymmetrical, has just one beginner and, as possible terms y, those to which this

* R. A. Fisher, *The Genetical Theory of Natural Selection*, p. ix.