

Book Reviews

Selected Papers in Statistics and Probability by Abraham Wald. T. W. Anderson *et al.*, Eds. Published for the Institute of Mathematical Statistics by Stanford University Press, Stanford, California, 1957. ix + 702 pp. \$10.

The development of a scientific discipline goes on at an uneven rate. Frequently, whole decades go by without major scientific advances; they are given simply to meticulous efforts aimed at perfecting the domain already covered. Then the monotony of this day-to-day routine is broken by the appearance of an individual of real talent. His papers reveal new ideas, formulate new problems, and break new ground. Occasionally, an old idea is rediscovered—perhaps one formulated long ago by another man of great talent and then overlooked by his contemporaries and forgotten. This old idea appears in a new light and becomes a basis for a new theory.

An incident of this kind recently occurred in the history of statistics. It was connected with the appearance on the scene of Abraham Wald. Born in Rumania and educated in Vienna, Abraham Wald came to Columbia University in 1938. Up to that time his interests had been directed toward various sections of pure mathematics. However, in 1937 he made a brilliant contribution to the foundations of the theory of probability. While in New York, Wald began to study the theory of statistics and, already in 1939, published one of his most important papers on the subject. Many other papers followed, quite a number of them written jointly with Wald's followers and students. This brilliant career was suddenly interrupted in the fall of 1950 when Wald, and his wife, perished in an airplane accident during a lecture tour in India. The statistical community in this country and abroad was deeply shocked and saddened. The present volume, which contains a collection of Wald's papers especially selected by a committee of the Institute of Mathematical Statistics, reflects the warm feelings of the statistical fraternity.

The achievements of Wald are many, and they are all brilliant. Because of the limitations imposed by the framework

of the present review, only two major points can be mentioned. One of these consists in the rediscovery of a very fruitful idea conceived at the end of the 18th century by Laplace, then briefly developed by Gauss and then, largely, forgotten.

As is well known, the general problem of mathematical statistics is to develop methods of using the results of observations subject to chance in order to draw conclusions regarding the chance mechanism that produces the observations. Laplace noticed that, in applying any such method, the statistician is very much in the position of playing a game of chance: if the chance mechanism produces "favorable" values of the observable variables, his conclusions will be right; on the other hand, if the chance variation provides him with "unfavorable" values of whatever he observes, his conclusions will be wrong. How wrong his conclusions will be also depends on chance. The possibility of the statistician's choosing among many possible methods of drawing conclusions corresponds, in a sense, to the possibility of a gambler's having something to say about the rules of the game he is about to play. In these circumstances, Laplace imagined that, with every decision made by the statistician as a result of dealing with some observations, there is connected a "loss" and that the greater the statistician's error, the greater the loss. From here on, there was just one step to the formulation of the basic problem of choice among the possible statistical procedures: select the one that minimizes the expected loss resulting from wrong judgments. Gauss' method of least squares is based on this same principle, except that Gauss' loss function is defined to be proportional to the square of the error committed. Curiously, while the method and, particularly, the machinery of least squares are generally remembered and widely used, the principle on which this method is based—that is, the idea of the loss function—was largely forgotten. Wald's work brought it back, and now it is being broadly developed. The novel developments are concerned with methods of drawing decisions which, in a sense, are optimum not for any particular loss functions, such as those contemplated by La-

place or Gauss, but for broadly defined classes of loss functions.

The second major achievement of Wald consists in the integration of the theory of statistics (theory of decisions based on observations subject to chance variation) with the theory of experimentation, to form what may be called the theory of experimental strategy. The honor of having initiated the theory of experimentation belongs to another outstanding contemporary statistician, R. A. Fisher. However, much as science owes Fisher, particularly for his ideas of randomization, the problems of experimentation considered by Fisher are concerned with the design of isolated experiments and may be termed the tactics of experimental work. Contrary to this, Wald's theory deals not with single experiments but with their totality in a given domain of study. In addition, using his ideas about sequential procedures, combined with the idea of the loss function for faulty judgments, Wald laid the foundations of an all-enveloping, unified theory of experimentation and statistical decision-making. This unified theory contemplates the possible cessation of experiments at each step and the adoption of a terminal decision regarding "the state of the universe" or continuation of experimentation with a novel setup.

These general ideas, combined with many brilliant particular developments, are reflected in *Selected Papers in Statistics and Probability by Abraham Wald*. It must have an honored place on the shelf of every scientific library and on the desks of most serious research workers.

J. NEYMAN
University of California, Berkeley

The Water Relations of Terrestrial Arthropods. Cambridge Monographs in Experimental Biology, No. 5. E. B. Edney. Cambridge University Press, New York, 1957. 109 pp. Illus. \$3.

The special difficulties encountered by terrestrial arthropods, because of their small size, in obtaining and keeping a sufficient supply of water have attracted the attention of many workers during the past quarter-century. In this small volume, E. B. Edney, who was, until 1955, reader in entomology at the University of Birmingham and who is now professor of zoology at the University College of Rhodesia and Nyasaland, reviews critically the literature in this extremely active field. The book will be of particular interest to insect physiologists, but comparative physiologists, ecologists, and biologists in general will welcome it. There are nearly 250 refer-