The Vectors of Mind. By L. L. Thurstone. (The University of Chicago Science Series.) University of Chicago Press, 1935. xv+266 pp.

It has been found by psychologists attempting to "explain" the correlations resulting from a set of tests, that the original Spearman hypothesis of a single common factor is generally untenable. The natural extension of the hypothesis is that the correlations can be explained by several common factors operating linearly. During the last few years this general hypothesis has attracted the attention of several investigators, particularly Hotelling, Kelley, and Thurstone. In this book, Professor Thurstone has given a detailed exposition of methods which he has developed for handling the multiple factor problem. He has found the theory of matrices to be an effective tool for treating the problem and has included a lengthy introduction on elementary matrix theory and linear transformations required for the subsequent pages.

Expressed in its simplest form the fundamental problem is essentially that of finding a matrix F containing as many rows as traits measured, and having the least number of columns and greatest number of zero elements (subject to various restrictions) such that, except for sampling variations, $FF'=R$, where F' is the transpose of F, and R is the matrix of correlation coefficients with variances due to common factors, as diagonal elements. The first two chapters are devoted to an elaboration of the nature of this problem and its mathematical formulation. By considering each trait as a point in the common factor space, a geometrical interpretation of the factor problem is developed along with its analytical treatment. In fact, most of the definitions are written in geometrical language.

A procedure for factoring R, called the centroid method, is developed in Chapter 3. This method consists of finding the elements of F from the matrices of several sets of transformations of the common factor space, each set being a cycle of rotations, translations, and reflections, designed to locate the centroid of a corresponding "residual configuration" of trait points. A method for finding an F from the orthogonal transformation associated with the principal axes is given in Chapter 4. This method is similar to Hotelling's method of principal components. In Chapters 3 and 4 the author deals mainly with the problem of finding an F with a minimum number of columns, so that, except for sampling variations, $FF'=R$. In Chapters 6–10, he is concerned with isolating primary traits, that is, a further trimming of F by transforming to new coordinates in the common factor space in such a way as to get (ideally) a maximum number of zero elements in F. Chapter 11 is a discussion of the regression method of appraising the primary traits in each individual. The book is well equipped with applications of the method to real as well as fictitious data. Several appendices of laboratory directions are given which are extremely valuable to those interested in applying the centroid method or the method of principal axes to actual data.

The author has presented an enlightening discussion of the multiple factor problem and methods for handling it. However, as many, if not more, problems are raised than solved, which is often inevitably true of works in a new field. The author scarcely mentions the sampling aspect of the multiple factor problem, which is a matter of considerable importance in an application of the method to as few as two hundred and forty individuals, (the number in a study reported by the author). For this reason the generality which he claims by not assuming normality is, for the most part, illusory. Of prime importance among the mathematical problems are those which arise in dealing with sampling variations. These would include the problem of determining optimum estimates of the elements in F, and in actually developing an objective criterion and its probability theory for testing the hypothesis that a set of correlation coefficients can be explained by an F which has been found by any method whatever. Further development of the multiple factor theory will depend largely upon solutions of these problems.

S. S. WILKS

Leçons d'Analyse Vectorielle. By Gustave Juvet. Part II. Paris, Gauthier-Villars, 1935. 306 pp.

This second part of Juvet's *Vector Analysis* contains the applications to mathematical physics. These relate mainly to potential theory, fluid dynamics, and electromagnetic theory. The book contains a good collection of exercises. To provide a basis for the fundamental existence theorems, a brief treatment of Fredholm's theory of linear integral equations is given and an appendix is included which contains the elements of the theory of functions of a complex variable. The mathematical discussions are of intermediate character, making use of conditions of continuity and convergence, but not stressing these matters as much as is customary in works on pure mathematics.

H. B. PHILLIPS

Science and the Human Temperament. By Erwin Schrödinger. New York, W. W. Norton, 1935. 24+192 pp.

Schrödinger writes: "The old links between philosophy and physical science . . . are being more closely renewed. The farther physical science progresses the less can it dispense with philosophical criticism." This book may be regarded as a substantiation of this thesis by means of an illuminating analysis of certain fundamental ideas and issues in contemporary physics.

The most important chapter is entitled *The Fundamental Idea of Wave Mechanics.* It presents the author's theory as a natural development of, and the first theoretical justification for, the similarity between Fermat's principle of minimum time in optics and Hamilton's minimum principle in mechanics. This and the entire previous chapter discuss the role of models in physics.

Two other philosophical issues receive extensive consideration. They are scientific law and causality. The universal reduction of statistical to causal laws is regarded as unjustified. Even the rigorous application of causality in Newtonian mechanics is queried. It required that velocity be determined in defining a state. But velocity was identified with a differential quotient which was defined as $(x_2-x_1)/(t_2-t_1)$ as $t_2-t_1\to 0$. Hence, the velocity referred "to two units of time and not the state at one moment." Against the coincidence of the two units in the limit, he adds that "possibly this mathematical process of approach to the limit . . . is inadmissible" and "is inadequately adapted to nature" (pp. 61–62).