The indispensable metallurgical-chemical and physiological background to alchemical practice in China was painstakingly built up.

Part 3 of the volume traces the history of Chinese alchemy from the first emperor through a "golden age" (end of Chin to late T'ang) and a "silver age" (late T'ang to Sung) to its ultimate decline. A short section sketches the coming of modern chemistry to China, from the Jesuit missions of the 16th century up to the scientific movement of the 19th century.

Two themes, familiar from earlier volumes of the work, recur in Needham's discussion of chemistry and chemical technology in China. One is the skepticism and lack of credulity of the Confucians—which may, at first sight, seem closer to the "scientific spirit." The Confucians consistently derided alchemical enterprises, pointing out (in the words of a treatise of the first century B.C.) that in alchemical arts "everything is vague and formless, like trying to tie up the wind or capture a shadow, and no result is ever achieved." But such skepticism remained part of an attitude that dismissed all inquiries into nature beyond a utilitarian minimum as a distraction from the moral concerns the Confucians placed at the center of culture. Scientific curiosity and achievements remained confined to the credulous but active Taoists.

The other theme is the contrast between gentlemen and sooty empirics. Persistent belief in the possibility of metallic transmutation over the centuries despite a simple and well-known cupellation test for gold puzzled historians of alchemy in the last century. In part 2 of this volume Needham explained it as the result of social barriers between gentlemen theoreticians and metallurgical artisans. More detail is now supplied to support that assertion. In the first century B.C. a Chinese emperor turned over the resources of the imperial workshops to the making of alchemical gold. The project failed. Needham suggests that the very fact that the failure was recognized demonstrates that the alchemical myth could not persist in places where artisans would normally subject it to the cupellation test. Hence the later emphasis on situating alchemical experimentation in recluse environments, away from worldly corruption—and also away from the keen and searching tests of thê artisan. How sharply the distinction can be maintained and whether it is just (or complimentary) to place the artisan's understanding of his own work in a theoretical vacuum will no doubt stimulate debate.

With two installments now published and three more to follow, the section on "chemistry and chemical technology" in Needham's massive study vastly increases our knowledge of that aspect of Chinese science. Fascinating cross-cultural comparisons are continually suggested. Information winnowed from Chinese and Japanese sources is supplemented by sources in the principal Western languages, and the bibliography in this part alone occupies 170 pages. An "author's note" contains interesting reflections on the way in which the prevalent view of the place of science in culture has changed radically in the 20 years during which the work has been in progress.

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A Statistical Technique

Discrete Multivariate Analysis. Theory and Practice. YVONNE M. M. BISHOP, STEPHEN E. FIENBERG, and PAUL W. HOLLAND. With the collaboration of RICHARD J. LIGHT and FREDERICK MOSTELLER. MIT Press, Cambridge, Mass., 1975. x, 558 pp., illus. $30.

The analysis of variance, regression and correlation analysis, and contingency tables are among the most commonly used statistical techniques. The analysis of variance is a technique to sort out how a number of factors, often presented in tables whose parts are labeled row, column, and block, affect a response variable, which is usually a measurement. The analysis is designed to find which factors are important and how they interact to produce the observed response. The analysis of variance dates back to the work of Ronald A. Fisher between 1925 and 1935 and reached a height of development with the work of George W. Snedecor between 1930 and 1940. In a sense, the analysis of variance is the workhorse of statistics.

Regression and correlation methods are used to measure the relationship between two or more variables. The term "regression" originated with Francis Galton in his studies on natural inheritance. The practical application of regression and correlation techniques became possible in 1915 when Fisher found the distribution of the correlation coefficient. During the next 20 years much of the classical theory was developed. Recently, activity in this area has revived, primarily because of the availability of computers and programs for multivariate regression models.

The format of some contingency tables may be similar to that of analysis of variance tables, in that there are categories referred to as rows, columns, and blocks. The difference is that there are not measurements in each cell, but only counts of occurrences. In other words, the response variable is now a discrete or counting variable instead of the continuous measurement variable of the analysis of variance. In such cases the analysis of a contingency table is similar to the analysis of variance in that the problem is to sort out the factors and interactions that affect the counts, and similar to a regression and correlation analysis in that the relationship or independence of factors is of interest.

Today the analysis of contingency tables is frequently referred to as the analysis of discrete multivariate data. The book under review is the first extensive exposition of this technique. It is designed for the researcher who is trying to uncover a possible underlying structure that gives rise to the observed cell counts. A recent study dealing with admission of students to Stanford University illustrates the type of data for which such an analysis might be used. There were a number of categories: financial variables, including amount of financial aid; geographical region; ethnicity; sex; previous family affiliation with the university; and, finally, a variable indicating acceptance of Stanford by the student. The problem was to detect the structure of the variables that influence students' choice among the universities to which they have been admitted.

The origins of contingency tables stem from Karl Pearson and Fisher, who did considerable initial work in the early 1900's on the 2×2 table (two rows and two columns). It is indeed surprising how many experiments are amenable to analysis in this format. Tests of independence of two sets of characteristics are explained in many basic textbooks. Even tests for such concepts as complete or partial independence in multidimensional contingency tables, introduced by Yule early in this century, have become standard. In the three-dimensional case, an attempt to define interactions was made as early as 1935 by M. S. Bartlett. The idea behind interactions is as follows. Suppose a number of different items are subjected to different treatments—for instance, different varieties of plants to different fertilizers. When interactions are present, treatment A may be better than treatment B for one variety but worse for another. Thus the treatments and the varieties are "interacting." If no interaction is present and treatment A is better than treatment B, then it is better for all varieties.

One comment about terminology may be in order. Normally, the term "analysis of variance" is used when one continuous variable is affected by one or several extraneous factors, whereas the term "multivariate analysis" is used when there are several variables, which may or may not be influenced by extraneous factors. Multivariate analysis of variance is a symbiosis of the two. The definition of interaction might be quite different for analysis of variance and for multivariate analysis. Discrete multivariate analysis and discrete multivariate analysis of variance are discrete analogs of the continuous versions. In this sense, the present book perhaps would be more aptly entitled "Discrete Multivariate Analysis of Variance."

The book is primarily a research handbook, and as such will be extremely useful. It was not really meant as a textbook and should not be considered as such. Although it could be useful for a seminar, its primary value is as a guide for the applied statistician. A review of the topics and contents of some of the chapters will help show the development of the subject.

Chapter 2 sets forth models for which the contingency-table format may be used. Of particular concern is the log-linear model. The reason for this is that under certain simplifying assumptions the logarithm of counts yields an additive model, so that there is an analogy with the analysis of variance. This analogy is exploited both notationally and in terms of the usual analysis-of-variance table in which there is an analysis of interactions.

Chapter 3 concerns estimation of the parameters by the method of maximum likelihood. Maximum likelihood estimates can be calculated by hand for relatively simple models, but a computer is almost essential for more complicated models. Some iterative calculation procedures are discussed.

Given the model and a method for estimating parameters, chapter 4 continues with a discussion of testing whether the actual data fit the model, that is, of performing a goodness-of-fit test. This procedure implies that an alternative model exists. Again there is a similarity with the analysis of variance in that the procedure is to test for higher-order interactions first and to continue in a hierarchical manner until the simplest structure that gives an adequate explanation of the observations has been obtained.

At this point the description of the method of analysis is complete. This much of the book is adequate for many, perhaps most, problems that confront the researcher. However, there are several additional technical problems that need to be dealt with.

The first problem is that there may be a good fit except for several aberrant cells. It is now generally accepted that between 5 and 10 percent of data collected are poor data, and in some instances the percentages may be as high as 20. Some discussion of outliers is provided in chapter 4.

A second problem concerns finding maximum likelihood estimators for models with structural zeros. Individual cell counts may be zero for either of two reasons. There may, by chance, be no observations in a cell, or a particular combination may be impossible. The latter case is called a structural zero. For example, a particular blood type may never occur with a particular racial composition. Estimation when structural zeros are present increases the complexity of the numerical analysis, and this is the subject matter of chapters 5 and 6.

In some disciplines—sociology, for example—models of change over time based on Markov chains have been of interest. Chapter 7 provides contingency table analyses for such problems. These models have already appeared in the applied literature in some fields, and are available in some textbooks.

Chapter 8 deals with a cross-classification-type contingency table in which the rows and columns represent similar categories. This occurs, for example, when the row represents a category for the right eye and the column a category for the left eye.

Chapter 9 provides some general discussion of practical aspects of selection of models and assessment of closeness of fit, including some do's and don't's. For example, on occasion a very excellent fit may be observed—indeed, too good a fit. The researcher should be wary if this occurs and check whether too many parameters have been fitted.

There are over 50 worked examples in the book, many of which are taken from research in which the authors participated. In almost every instance the examples are new and interesting, and they cover a wide range of applications. Computer programs are not included in the text. Some programs are available (as is noted in the text), but one has to know where to obtain these. It would be most helpful if the authors would publish their programs in a standard journal or make them available to interested readers. This would avoid a tremendous amount of redundant effort, as well as allow the practitioner to assess the numerical accuracy of the computations.

In summary, this book is the first that gives a general account of the analysis of multidimensional contingency tables. It provides a comprehensive coverage of the subject with numerous examples that can serve as models for the reader. The book is at a sophisticated level and requires reasonable familiarity with statistical theory, yet it is readable. Both the professional and the applied statistician will want to review the techniques covered in it and make them part of the standard repertoire. In the future a number of texts on this subject will no doubt be written, some at a more elementary level, but the present book will almost certainly serve as a foundation for them.

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Feeding Behavior

The Ethology of Predation. EBERHARD CURIO. Springer-Verlag, New York, 1976. x, 252 pp., illus. $29.60. Zoophysiology and Ecology, vol. 7.

The study of how and why animals feed the way they do is central to an understanding of ecological processes at all levels. Eberhard Curio restricts his book mostly to animals that feed on other animals of similar or lesser size. At the beginning, Curio explicitly adopts the inductive rather than the hypotheticodeductive approach. What results is a virtually complete catalog of the facts of predation. The assembling of this information is a great service to research specialists, but while most aficionados probably will wish to own the book, few will read it in toto. Indeed, the voracious reader may contract indigestion.

Its five chapters unfold as in a predatory sequence: motivation, search, recognition, selection, and "hunting" (this last covers all behavior subsequent to a decision to attempt to feed on a particular item). I found several discussions especially intriguing. The choice of prey can be made item by item (as is the case