Book Reviews

Statistics in Biology

Biometry. The Principles and Practice of Statistics in Biological Research. ROBERT R. SOKAL and F. JAMES ROHLF. xxii + 778 pp., illus. $15. Biology Series. **Statistical Tables.** F. JAMES ROHLF and ROBERT R. SOKAL. xiv + 258 pp. Cloth, $7.50; paper, $2.75. Freeman, San Francisco, 1969.

As a first approximation, it is true that statistics is statistics. An introductory course in biometrics is likely to cover much the same material as one in, say, psychometrics or technometrics. There are nevertheless important differences in emphasis and to a smaller degree in content, and these differences are probably greater than most differences among courses within any one of these areas.

In the preceding paragraph I have made an argument in the form of what is, rather misleadingly, called analysis of variance. As Sokal and Rohlf note, this approach is more widely applicable than are precise statistical tests based on it; it "provides an insight into the nature of variation of natural events, into Nature in short, which is possibly of even greater value than the knowledge of the method as such. If one can speak of beauty in a statistical method, analysis of variance possesses it more than any other."

A discursive approach characterizes this book more than almost any other serious text I know in statistics. This is not to say that Sokal and Rohlf neglect the formulas and computational methods that form the meat of their subject. Rather, computational methods are segregated from the running text into "boxes," some of which continue for several pages. The text itself gives the motivation and theoretical background necessary if one is to use these methods intelligently, and explains their general operation.

The mathematics is the minimum consistent with adequate understanding of the context in which the methods can be used. An appendix contains some derivations too long for the text, but even here no calculus is used. The book nevertheless includes one or two original theoretical results, as well as material that makes it unconventional in important respects. There are detailed instructions for operating desk calculators, and 76 pages of computer programs with instructions for their use. These methods are widely available, but good program libraries and efficient procedures are far from ubiquitous, and the demonstration of these modern methods will probably save much anguish for occasional users.

Analysis of variance receives more attention than usual, but unfortunately this relegates the general *t*-test (in my experience the most common statistical test of any kind) to the latter part of the book, where it is recommended only for unusual situations. Randomization tests and the combination of probabilities, also hardly ever mentioned at the introductory level, are important and receive due notice here. A geometrical comparison of the basic multivariate methods would have been illuminating.

I was disappointed to find not even a mention of the general Bayesian approach, which has many simple applications even if it is inordinately complex in its full development, and which provides a way of looking at the world that is more encompassing than the more ad hoc methods of traditional statistics. Frequentist interpretation of probability leads to a narrow interpretation of confidence limits. Sokal and Rohlf take a strictly Neyman-Pearson approach, even to the extreme of applying the accept-reject dichotomy to all cases of statistical testing. If I find a probability value of 0.07, I have less confidence in the hypothesis than if the value is 0.20, but this continuum disappears when fixed significance levels are used even in cases where they are unnecessary.

Although the authors wisely emphasize the robustness of most parametric methods, they do include a nearly adequate treatment of nonparametric methods. The main lack here is of a realization of the sensitivity of estimations and tests on variances to deviation from normality of the underlying distributions. The important coefficient of variation has even poorer treatment than in most texts, which is particularly unfortunate because of the existence of an adequate test, discovered independently a couple of years ago by three biologists. The discussion of the number of significant figures to use would have been more convincing if the principles it sets forth had been followed elsewhere in the book. And a hypothesis suggested by the data cannot, unfortunately, be treated as though it were an initial hypothesis unless there is some way to allow for all other possible results of any kind, not just of the kind noticed, with as low an initial probability. The companion book of tables is largely conventional; their replacement by graphs would in most cases permit more accurate results with the same use of space. All these faults are common ones; it is the more important to understand them.

The authors are practicing biologists, and their approach is more relevant to real biological concerns than is that of most texts. The book seems easily readable, and in this it is nearly unique, although the final test must be by students. The problems seem excellent. The cryptically complicated matter of correlation and regression, often or perhaps even usually misinterpreted by statisticians, receives the best general treatment I have seen. A great deal of biological work is sloppy because many biologists don't understand basic statistical concepts. This book should help to remedy this and in doing so supersede Snedecor, Bliss, and the rest; despite its faults it is easily the best introduction to biometrics, and perhaps to applied statistics generally, that is available.

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The Operon Reexamined

Nucleus and Cytoplasm. HENRY HARRIS. Clarendon Press (Oxford University Press), New York, 1968. xvi + 142 pp., illus. $7.

The year 1961 was a big one for molecular biology. That year saw the first evidence for the existence of a messenger class of RNA molecules which carried information for protein structure from the nuclear genes to the cytoplasm. In that year, too, the deciphering of the genetic code was begun by employing artificial messenger RNA molecules to synthesize proteins in vitro; and Jacob and Monod presented their elegant model that explained gene regulation as the control of the transcription of genic information into messenger RNA. The sense of fundamental progress was so impelling in those days that experimental evidence may not have received the careful critical scrutiny it would have in less exciting circumstances. In view of the extent to which the major tenets of molecular biology have pervaded current thinking and are guiding research on development, behavior, and evolution, a critical consideration of these tenets seems called for.

This slim volume by Henry Harris is a laudably lucid contribution to meet the need. While Harris analyzes a number of issues, including the question of the physical state and stability of the messenger, his most important undertaking is to challenge the idea, given powerful impetus by the Jacob-Monod operon model, that cell differentiation consists in the selective "turning on" or "turning off" of gene transcription. Harris reveals weaknesses in the evidence and arguments that have been presented in favor of this idea, an idea that was based originally on work with bacteria. Studies of eukaryotic microorganisms, particularly the marine alga *Acetabularia*, and hybrid cells of higher organisms provide, on the contrary, impressive support for the view that regulation is a cytoplasmic activity. In these organisms the messengers of the genes are relatively long-lived, and their expression appears to be mediated by events taking place in the cytoplasm. The concept that regulation and cell differentiation in eukaryotes occur in the cytoplasm does not require, however, any revolutionary overthrow of molecular genetics; the basic model of gene action and control can readily assimilate this view. It is possible to imagine, of course, that regulation and differentiation may sometimes occur directly at the gene level, and at other times in the cytoplasm, where protein synthesis is known to take place. With so much attention in developmental and cell biology being devoted these days to chromosome "puffs," heterochromatization, histone inhibition of gene transcription, and other indicators of controlled gene activity, Harris's book serves the useful purpose of warning against premature narrowing of research and neglect of the cytoplasm.

Possibly eukaryotic cells differ from bacteria in the mechanisms by which regulation is achieved. Harris does not think so, for he believes the evidence is not convincing that gene transcription is regulated even in bacteria. In this respect I think Harris overstates his case. Unfortunately, his book was written before the repressors of bacterial beta-galactosidase synthesis and of lambda virus replication were isolated and described in some detail. The properties of these repressors offer persuasive support for the hypothesis that, in bacteria at least, genetic regulation occurs at the level of the gene itself.

The skeptical, critical approach of Harris may put off some readers, but I recommend it as a necessary, if bitter, antidote for the enthusiastic, uncritical reception that the model of gene regulation has received in some laboratories and schools. Few will end their reading of this book without a sober reevaluation of the complexity of cell differentiation and of the molecular evidence on which current views of gene action are based.

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How Weather Has Been Measured

Invention of the Meteorological Instruments. W. E. KNOWLES MIDDLETON. Johns Hopkins Press, Baltimore, 1969. xiv + 370 pp., illus. $12.

Human ingenuity did not begin with the space age. It may surprise many to see just how ingenious the forebears of the contemporary scientist and technician were. It may also comfort and instruct today's researcher to take a backward glance at the hang-ups of his clever predecessors. Knowles Middleton's new book *Invention of the Meteorological Instruments* presents us with both opportunities. His scholarly chronicle, which stops short of the space age (or even the atomic age), leaving that story to, as he puts it, "more knowledgeable pens," takes up in order the development of instruments for measuring atmospheric pressure, temperature, humidity, rain, evaporation, wind, duration of sunshine, upper winds, and height and motion of clouds, and combinations of these instruments in the form of meteorographs. It is rich in original source material and painstaking detective work that took the author to many of the historical scientific centers and libraries of Europe.

Though the book is in no way a treatise on physical principles, one is inclined in reading it to reflect upon them. The question Just what is temperature anyway? will occur to the thoughtful novice as he reads about the uneven, hazard-strewn evolution of thermometers and temperature scales. And the more sophisticated reader may also ponder what his concept of temperature might have been some hundred years ago. The development of the aneroid barometer provides an example of the constraints that his own point in time can put on the instrument-maker. The original idea for this type of barometer preceded its actual construction by 300 years, apparently because of the generally accepted belief that metals were slightly porous.

The names made famous by textbooks appear, but well diluted by a welter of unfamiliar ones. So much work was done by scientists now obscured by the passage of time. The author gives them new and deserved exposure. And some of the well-advertised names pop up in surprising contexts. The inventor of the Wheatstone bridge, familiar to every physics student, is credited with designing an anemometer whose sensor was a suspended sphere. Even names famous outside the sciences appear now and then. For example, Sir Christopher Wren, the renowned 17th-century British architect, designed a number of meteorological instruments, including the first tipping rain gauge.

A serious work, this book still offers whimsy for those who have an eye for it. In reading about the ideas put forth by these imaginative minds of the past one encounters a wide spectrum of alternative solutions to a given problem. Some are bound to be out of the ordinary, enough so to provoke a smile. One type of early hygrometer sensed changes in humidity by utilizing a small vessel made of humidity-sensitive material, which was attached to a glass tube much in the fashion of the bulb of a mercury thermometer. As the vessel expanded and contracted with changing humidity the mercury would fall and rise in the tube. Elegant bulbs of very thin ivory were fashioned for