may feel that I can reject H_0 as implying that the observed data represent too improbable an occurrence. Since Edwards does not pursue this line of reasoning, he does not exhibit the notable distinctions between likelihood testing and tail area testing. For example, 2-unit support limits for a normal mean, while implying an approximate 5-percent significance level in terms of tail area, correspond to a likelihood improbability factor of only $1/e^2 = 1/7.4$ relative to the most likely value, thus showing that likelihood testing implies wider limits than tail area testing. This type of distinction is generally true, and may be the price to be paid for the use of the logically more satisfying concept of likelihood.

The direct interpretation of likelihood deserves more exploration and ultimately more use. Edwards's book, despite its limitations, is therefore welcome as part of a healthy movement in statistics.

A. P. DEMPSTER
Department of Statistics, Harvard University, Cambridge, Massachusetts

A Complex Sediment

Till. A symposium, Columbus, Ohio, May 1969. RICHARD P. GOLDTHWAIT, Ed., assisted by Jane L. Forsyth, David L. Gross, and Fred Pessl, Jr. Ohio State University Press, Columbus, 1972. xii, 402 pp., illus. $20.

When a symposium volume provides basic material suitable for students and interpretative articles that will provide for years of dispute, then it should have a wide audience. George W. White, a long-time till enthusiast and teacher of glacial geologists, to whom this volume is dedicated, sets the tone for the collection by warning us against the "naive assumption that till is till." The contributors to this volume are geologists, soil scientists, and agronomists and are from state, provincial, and national geological surveys, research councils, and academic institutions. Their combined work shows that till is a complex sediment whose niche in the glacial history of an area is not yet clearly understood everywhere.

An introductory chapter by R. P. Goldthwait is a fine summary of till, its origin, transport, and deposition; an excellent bibliography provides a guide to the scientific background. Goldthwait is particularly suited to write such an introduction because of his long association with field problems in glacial geology in many parts of the world. It is also appropriate that one of the most indefatigable field and laboratory workers in till studies, Alexis Dreimanis, should present a summary that details how a large number of geologists in North America classify and study till, and also a later paper on the distribution of rock and mineral fragments in till.

The disputes will arise from many articles. Under the general heading of Genesis, individual papers vary from a simple enlargement on previously published material (Stewart and MacClintock), which makes a simplistic, unsubstantiated explanation of till fabric preserved in an "ablation till," to the detailed, meticulous field and laboratory work of Boulton in Spitsbergen and Pessl in Connecticut. An article by Drake on the genesis of tills found in New Hampshire strikes a glancing blow at the problems encountered in New England, where the combination of topography and lithology makes it difficult to identify lodgment and ablation till. Indeed, the attachment of genetic names to till bodies without sufficient evidence may do more to block a real understanding of the origin of tills than any other act.

The section on Thickness and Structure includes studies on large-scale block inclusions in Saskatchewan, stacking of single sheets of till, and the succession of relatively thin sheets of till in northeastern Ohio and northwestern Pennsylvania and, curiously alone in this field-oriented symposium, a paper on theoretical rates of till deposition on irregular topography.

Several authors write on Stratigraphic Correlations, which are perhaps not as immediately useful in trying to understand the origin of till but which are certainly important as regional building blocks in the construction of Pleistocene history. Others contribute to a section on Composition, in which details of mineralogy and grain size are used to identify and differentiate till sheets.

J. T. Andrews, an exacting worker in the field of till fabrics, warns of the lack of reliability of ordinary till-fabric diagrams and touches on the many pitfalls in fabric studies. Yet it seems that some clear directional trends, which agree with other directional indicators, are shown in rose diagrams from relatively widespread single-sample localities (as in articles by Evenson and by Ramsden and Westgate). Although only four papers are listed in the section on Fabric, four other papers (under Genesis) use till fabric as the basis for their presentations.

A paper on a Pleistocene mudflow, by Hester and duMontelle, brings up a question I raised many years ago in mapping in New England: how much ground moraine truly is emplaced as subglacial till and how much identical-appearing till is superglacially derived flowtill deposited singly or in layers from the last large ice blocks to melt away. If both superglacial and subglacial tills can appear identical, or nearly so, as shown by studies in this symposium and elsewhere, then many parameters must be studied, both in the original environment (as by Boulton) or in the landscape abandoned by glaciers (as by Drake). Boulton unknowingly paraphrases a thought that T. C. Chamberlin wrote to N. S. Shaler of Harvard in 1885, one that applies not only to till fabric and till genesis, but also to the whole field of glacial geology—the truism that "so many different processes can produce similar results."

Goldthwait's summary introduction, the field data, and the inferences presented in this collection ought to be available to every glacial geologist, for much can be derived from the study of them. It is too bad the editors were not more exacting: "sheer planes," poorly reproduced and out-of-focus photos, references not cited or incorrect, typographical errors, and numerous misspellings mar the smooth reading. But these are really small complaints to set against the conception and usefulness of this symposium volume.

JOSEPH H. HARTSHORN
Department of Geology/Geography, University of Massachusetts, Amherst

Scattering Phenomena

Raman Spectra of Molecules and Crystals. M. M. SUSCHINSKII. Translated from the Russian edition (Moscow, 1969). Israel Program for Scientific Translations, New York, 1972 (distributor, Wiley, New York). x, 446 pp., illus. $34.

Most scientists working in the field of Raman spectroscopy no longer dwell on the physical nature of the scattering process, but instead consider Raman scattering as an analytical technique for investigating the structure of matter. Authors writing on the subject have neglected detailed discussions of the physical basis of Raman scattering in favor of more involved treatises on experimental techniques or chemical

applications. Not since G. Placzek published his *Rayleigh-Streuung und Raman-Effekt* in 1934 has a text dealt in a systematic way with the basic topics necessary for a thorough understanding of the physical phenomenon itself. Suschinskii's main purpose in writing this text was to fill this void, and he has done an admirable job. The first quarter of the book treats the general theory in a clear and concise manner, suitable for reading by anyone with a basic knowledge of quantum mechanics. Of particular interest is the theoretical discussion of resonance scattering phenomena. Unfortunately the few brief words the author writes concerning the experimental status of resonance scattering are sadly out of date. But because of the publishing time involved, this situation will never be remedied by a textbook as long as the field of Raman spectroscopy continues to grow as rapidly as it has for the past decade.

A secondary objective of the author was to highlight the various possible applications of Raman spectroscopy to the study of molecular and crystal structure. This aspect of the book broadens its potential audience considerably. In addition to the standard discussions of molecular symmetries, the text also includes a section on the structural analysis of various organic substances which should prove quite useful to organic chemists and biophysicists. Besides covering selection rules for first- and second-order scattering from perfect crystals, the author brings us more exotic subjects such as scattering near structural phase transitions and scattering from powders. Indeed, most of the material covered in major review papers on Raman scattering is discussed at least briefly. Stimulated Raman scattering is also covered in some detail. Although the discussion of stimulated scattering is quite complete, it is hard to find material that has not been treated extensively in a number of other texts.

Perhaps the greatest value of the book lies in its bibliography. It includes over 500 references, the majority of which are from Russian journals. These references should assist greatly in informing the English-speaking scientist of the vast amount of work being done with Raman spectroscopy in the Soviet Union.

LAWRENCE S. WALL
Department of Physics, Colorado State University, Fort Collins

Quantum Mechanical Ideas

Perspectives in Quantum Theory. Essays in Honor of Alfred Landé. WOLFGANG YOURGRAU and ALWYN VAN DER MERWE, Eds. M.I.T. Press, Cambridge, Mass., 1971. xl, 282 pp., illus. $17.50.

About half of the 19 papers in this volume are on miscellaneous applications of quantum mechanics. No attempt will be made to review these here. The remaining papers are on fundamental questions, appropriately so in a book dedicated to Alfred Landé, who is among those pioneers of quantum mechanics who became increasingly critical of the orthodox line on the subject.

The most iconoclastic of the authors are Park and Margenau. In an analysis of the measurement of "incompatible" observables they conclude that it is the quantum mechanical axioms of von Neumann which are incompatible. However, this turns out to be largely a question of the semantics of the words "measurement" and "observation." It illustrates the danger of using as technical terms words in common use with rather wide meanings. Narrowing down the issue, Margenau and Park end by posing a fairly well-defined question: can one find, assuming conventional quantum mechanics, a procedure which (for an arbitrary state of the system) will yield a joint probability distribution $\rho(p, q)$ such that integration over q or p yields the conventional probability distributions for the other of the pair of incompatible observables? Margenau and Park illustrate procedures which work in this way for special states of a system, but leave the question open for arbitrary states.

As it happens just this question (it seems to me) is answered by Wigner in his elegant contribution "Quantum-mechanical distribution functions revisited." This includes a proof (previously unpublished) that there is no such positive distribution bilinear in the wave function and its complex conjugate. Assuming that all possible statistical predictions about a system are contained in the density matrix, the question of Park and Margenau is then answered in the negative.

The nonlocal nature of quantum mechanics is a source of unease for many people. There is an analysis of this by Karl Popper, writing on the Einstein-Podolsky-Rosen paradox. He emphasizes that it is more the instinct for locality than determinism which makes for the feeling of paradox here. It can indeed be shown that the quantum mechanical correlations cannot be reproduced by a hidden variable theory even if one allows a "local" sort of indeterminism. For example, one could imagine that the indeterminism might be introduced by throwing dice at every space-time point and allowing the result of each throw to influence physical events in the future light cone of the point in question. This would not work; the quantum mechanical correlations are too perfect to permit any such local statistical slop. Popper remarks that he does not find this point manifest in my own paper on the subject, but it is there—very briefly.

The least iconoclastic authors in the volume are Bondi and Rosenfeld. Landé, it seems to me, has been less troubled by the content of ordinary quantum mechanics than by its orthodox presentation. Bondi follows him in this, urging a serious attempt to find how quantum mechanical ideas may be most economically and convincingly inferred from everyday phenomena like the stability of solids. He feels that "if one percent of the effort spent on physics were devoted to clarification, we could soon teach the basic concepts of quantum mechanics to the general run of nine-year-olds." He is supported in this, in perhaps an unexpected way, by Rosenfeld, who describes some experimental investigations on human perception. Rosenfeld finds that some of the stages passed through by the child, in his notions of causality for example, are more in harmony with quantum ideas than with those of classical theoretical physics.

In addition to several other scholarly discussions of puzzles of quantum mechanics and the papers on applications already mentioned, there is some historical material. This includes some reminiscences of Born and a survey of Landé's work by Yourgrau and van der Merwe. Both of these articles include the following remarkable story, not previously known to me. Born and Landé worked together on the bulk properties of crystals according to the old Bohr quantum theory. For a time they were quite unsuccessful in getting agreement with experiment. Finally they succeeded, by giving up the idea that the orbits of electrons in an atom are coplanar. This "caused quite a stir" because "the mere analogy of Bohr's orbits with those of the planets around the sun, repeated over and over in the