summary of existing knowledge about motion and regimen in glaciers, glacial erosion, genesis (though not stratigraphy) of glacial deposits, and effects of frost action in the ground.

This list is nonhistorical, and is perhaps better adapted to a geographic than a geologic curriculum. Nevertheless, its material is well selected, and it is primarily analytical rather than descriptive. The presentation is not didactic; it consists in large part of summaries of competing ideas about glacial processes, with a summary at the close of each chapter embodying guidance through the data and opinions discussed. Under some topics are outlined theories no longer accepted, along with more recent, better ones. This procedure has value for students, although its usefulness for reference is slight.

The authors display a good command of the literature—no inconsiderable feat in these days—and the work as a whole is about as up to date as the treatment of so broad a theme could very well be. Each chapter is followed by a generous list of references, by no means confined to publications by geographers.

The book is easy to read; the ideas are clearly and pleasantly expressed. Illustrations, though not abundant, are well selected, and, in this field at least, good text is worth more than the same space devoted to maps, diagrams, and photographs. The book should have appeal not only to students but also to nontechnical readers with curiosity about glaciers and how they act on the land.

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History of Astronomy

Vistas in Astronomy. Vol. 9, New Aspects in the History and Philosophy of Astronomy. First Joint Symposium of the International Astronomical Union and the Union Internationale d'Histoire et de Philosophie des Sciences, Hamburg, Germany, Aug. 1964. ARTHUR BEER, Ed. Pergamon, New York, 1968. xvi + 320 pp., illus. $22.

In August 1964, more than 80 scholars from 18 countries met at the University of Hamburg for the first joint symposium of the International Astronomical Union and the Union Internationale d'Histoire et de Philosophie des Sciences. This newest volume of the *Vistas in Astronomy* series is the (slightly augmented) record of that symposium.

As a first step in conveying the nature of its contents, it will be well to point out that the volume's subtitle, "New Aspects in the History and Philosophy of Astronomy," is somewhat misleading. The discussion is exclusively and explicitly concerned with "promoting progress in the study of the History of Astronomy." The discipline called Philosophy of Science is represented in only the most marginal way. What was apparently intended by the reference to philosophy of astronomy was that there should be some philosophizing about the goals and methods of research in the History of Astronomy; but, as B. Sticker complains in the introduction, the contributors showed little inclination to let down their hair and address themselves to "the tools of the trade rather than the products." While their reluctance will doubtless prove disappointing to some professional historians of astronomy, it has almost certainly resulted in a book that holds more interest for the lay reader.

As much as the symposium members might be accused of failing in the one rather esoteric respect, they responded enthusiastically to the more familiar task of presenting "new aspects in the history of astronomy." Easily the most striking feature of the book is the diversity among its constituent articles. The most exciting of these is O. Gingerich's outline of "Applications of high-speed computers to the history of astronomy." Clearly, the potentialities are enormous. In an interesting turn of the tables, A. Beer illustrates that the history of astronomy can itself be fruitfully applied as a tool in the "Astronomical dating of works of art." Among several good historiographical essays, F. Hammer's summation of the major "Problems and difficulties in editing Kepler's collected works" stands out not only because of the importance of its subject, but for its general relevance to the similar projects that certainly ought to be undertaken in the future. Running along more familiar lines are articles such as those by M. Hoskin and, especially, H. Dingle ("A re-examination of the Michelson-Morley experiment"), which provide excellent examples of sophisticated historico-philosophical analysis. Finally, there are the inevitable chronicles that still constitute much of the effort devoted to every branch of the history of science. Limited in intellectual content and pertinent primarily to the specific histories of various national cultures, they represent, at best, raw material that will eventually be integrated into the general history of astronomy, at worst, new aspects that will prove to be blind alleys for the discipline.

As one ought certainly to be able to expect from such an expensive volume, the production is superb. Among the more than a hundred photographs included are many beautiful reproductions of old astronomical instruments. The volume is even indexed. The one thing that can be said to be lacking is thumbnail sketches of the contributors, who are identified only by their academic titles. American readers will be happy to find that, although over two-thirds of the contributions are from continental scholars, virtually all of the articles are in English.

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A Model of the Mind

The Nature of Human Intelligence. J. P. GUILFORD. McGraw-Hill, New York, 1967. xiv + 538 pp., illus. $14.75.

Nobody really understands the nature of human intelligence, but the impact of factor theory has made it clear that a simple IQ, as manifested in the Stanford-Binet or some other single index, is blatantly inadequate. Guilford's recent book summarizes the available evidence which has accumulated via multiple factor analysis—a method initiated by Spearman in 1904, reformulated as an application of matrix algebra by L. L. Thurstone in the 1930's, and further developed and given psychological substance by Guilford and others for the past 30 years.

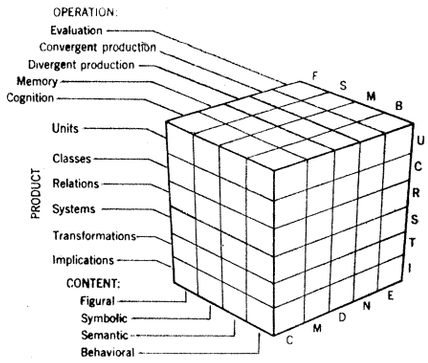
Guilford's book is an elaboration of his structure-of-intellect (SI) model, which is an orthogonal, three-dimensional taxonomy of 120 elements or "factors" of intelligence. The three major axes of this periodic table of intellectual processes are Contents, Products, and Operations. Each element of this cube is a hypothesized factor, 82 of which have been empirically confirmed. Such factors occur at the intersections of the 4 by 5 by 6 matrix reproduced on the next page.

Guilford embeds this SI model in the context of information theory by re-

garding each of the 120 components as different ways to process information. New inputs, for example, are processed via 24 cognitive abilities, such as the cognition of semantic units (as in vocabulary tests), the cognition of figural units, and the cognition of figural transformations (both spatial-visualization factors). Information already in storage, but capable of being retrieved, is processed via the 24 memory mechanisms. The production of new information—what we think of as creativity—occurs via the 24 "divergent" information operations, whereas those problem-solving tasks which logically lead to only one possible solution are reached via the proper combination of "convergent" operations.

The remainder of the book (about two-fifths) is devoted to relating Guilford's theory to relevant theoretical aspects of learning, perception, cognition, and creativity, as well as an examination of the major determinants of intelligence (heredity, brain mechanisms, social and cultural variables, and intellectual factors as a function of age). The essence of Guilford's message to mainstream (especially behavioristic) learning theorists is that the association principle, which they wish to apply to all learning, is relevant to only one of Guilford's six kinds of intellectual products ("implications"). His main message to theorists in other related domains is that they have also oversimplified, particularly in failing to deal with the multiplicity of processes, whether they be perceptual, learning, creative, or cognitive in nature. He backs this up with various specific examples, such as, in an analysis of human serial learning, by showing the differential involvement of cognitive and coordination factors in the development of psychomotor skills, and by elaboration of the 24-cell matrix of divergent production abilities which are so important in creativity.

Guilford's book is important. Why? Because it is a synthesis of some 60 years of effort to understand the nature of intelligence; because it provides a basic taxonomy for thousands of previously unrelated empirical studies; in short, because it provides a degree of order where there was chaos. It is, in fact, the most penetrating and comprehensive summary of the factorial attack on the problem of intelligence, and it will probably take its place in history as a 20th-century classic. What's wrong with it? Nothing really, other than the usual incompleteness which is characteristic of any scientific theory. Its most



Guilford's structure-of-intellect model, with three parameters. Other parameters may be added. [From *The Nature of Human Intelligence*]

obvious incompleteness stems from its static quality—its inability to deal with the dynamics of intellect. In short, Guilford's SI model is what it purports to be, a statement of the *structure* of intelligence, a statement which roughs out a basic taxonomy of what we are up against if we wish to understand the full complexity of how man processes that which is discriminable. Details of functional significance, dynamics, brain correlates, and the biochemical and experimental manipulation of each of the 120 processes—all this can follow. Guilford, in fact, does a scholarly job of bringing together the available empirical evidence regarding the biological and cultural correlates of factors, but the story is just too incomplete to add up to much. We get various exciting leads, however, such as (i) the various agnosias and aphasias as the most suggestive findings for correlating intellectual factors with brain functions; (ii) definitive evidence that the genotype makes a difference; (iii) definitive evidence that cultural deprivation and enrichment also make a difference; and (iv) differential life-span growth and decline curves for a large number of factors.

There are serious technical issues, however, such as Guilford's obvious bias in favor of an orthogonal model over the less restrictive oblique model, the mere adoption of information theory *terms* rather than a tight, systematic, information theory *analysis*, and the problems of factor matching and factor invariance. Guilford is aware of these problems, but he is not able to offer convincing solutions to them. It is highly probable that the orthogonal-oblique issue will eventually be settled on empirical grounds, and that a more analytic wedding of information theory and factor theory is just a matter of time. Factorial invariance, however, is much more intractable. In spite of some dozen mathematical solutions in the literature of the past decade, it may well be that the general case, involving different subjects and different (that is, nonoverlapping) measures, is unsolvable in principle. In my opinion this issue is crucial, although not devastating. It does mean, however, that Guilford's SI model (and anybody else's model) is presently based on qualitative or subjective judgments of factor identification. A quantitative index of factor similarity, based on identification of a given factor by multiple studies rather than by rotating two test batteries into a common space, is what is required to alleviate the present difficulty.

In this book we see one of the reasons why Guilford enjoys his reputation as one of the most distinguished psychological scientists of our time; for in his work he manifests a rare combination of qualities—namely, the nonmethodolatrous but sophisticated utilization of quantitative analysis under the control and direction of a broad and deep scholarliness which brings together all (or most) of the relevant empirical work. Is this not what science is about? And has anyone else brought forward a more viable theoretical structure which will account for intelligence?

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Works of a Statistician

Collected Papers. Contributions to Mathematical Statistics. S. S. WILKS. T. W. Anderson, Ed. Wiley, New York, 1967. xxxiv + 693 pp., illus. $12.50. Wiley Series in Probability and Mathematical Statistics.

S. S. Wilks (1906–1964) went to Princeton in 1933 as an instructor in mathematics and continued there, ultimately as a professor in the Department of Mathematics and as director of the Section of Mathematical Statistics, until his death. He was internationally known and respected as research worker, teacher, author of textbooks, editor, and, especially during and after World War II, as a propagator of statistical and mathematical ideas over a wide field, particularly in the U.S. government service. A good number of the most distinguished mathematical statisticians in the United States were research students under his direction.