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SCIENTIFIC BOOKS

Statistical Method. By Truman L. Kelley. New York, The Macmillan Company, 1924. xi + 390 pp. + 1 nomogram.

We are living in a period of tremendous increase of interest in statistics—vital, educational, business, economic, and so on. When I was in college, only 25 years ago, it would have been difficult to find a course in statistical theory or even one in which statistical methods were widely used—perhaps least squares as a way of reducing astronomical observations and the kinetic theory of gases as a branch of the theory of heat were the only available courses. To-day an undergraduate might almost obtain a liberal education from statistical courses alone. It is natural that there should be an increasing text-book literature of statistics and of its special fields. Yule's introduction appeared in 1910, is now in its sixth edition, and remains unexcelled in its own way. We have simple books by King and Secrist directed chiefly toward the student of collegiate economics, special works on vital statistics by Whipple and Pearl for the student of public health, and an excellent general text by D. C. Jones. At the moment the latest addition is Kelley's "Statistical Method." Written by a professor of education, it is evidence of the seriousness with which such professors have come to take elaborate statistical investigations.

Kelley's book is not easy; although not primarily a mathematical treatment of its subject, a moderate use of calculus is not made the occasion for apology. The author believes that the elementary statistical needs of biologists, economists, educators and psychologists are about the same and that a book can be written to provide a common foundation for the needs of all. This is good pedagogy. If a mature investigator finds his training in some subject, such as statistics, inadequate for his needs it may be that he can fill the lacuna easiest by a special treatise in which problems in his field (and in no others) are subjected to analysis by that method; if a student of the public health must learn vital statistics it may be that a special treatment such as Whipple's or Pearl's may most easily and rapidly meet his necessities; but if the student is caught young enough he undoubtedly profits most by a general discussion of a subject with illustrations from a variety of its applications and with emphasis on the method rather than on the particular problem used as illustrative material.

The author especially requests critical analysis of his determinations of probable errors and states that he has pursued the policy that as shrewd an estimate as possible of the probable error of a statistical constant is better than no estimate at all. I desire to commend this policy; it is very important for the student of statistics to be mindful of the fact that his is not an exact science and to have constantly before him some estimate of his probable errors. And in this connection, being invited by the author to criticize, I should like to say that I do not approve of carrying numbers out to so many places as he occasionally and others habitually do. These places, when repeatedly used, give a psychological impression of exactness which has an opposing effect to that of the estimate of probable errors; any book which would be sound in practice on probable errors should give considerably more attention than Kelley's does to the matter of significant figures.

A list of titles of the chapters is the quickest way to show the scope of the book: "Tabulation and plotting of (statistical) series," "Graphic methods," "Measurement of central tendencies," "Measures of dispersion," "Normal probability distribution," "Comparable measures," "Fitting of curves to distributions," "Measures of relationship," "Functions involving correlated measures," "Further methods of measuring relationship," "Multiple correlation," "Statistical treatment of sundry special problems," "Index numbers." The method of treatment is essentially Pearsonian, small attention being given to the methods of Edgeworth and the Scandinavian School, but the author does not dismiss in a cavalier fashion the possibility and even probability that such methods may be very useful. On the whole, that shrewdness which he has shown in the estimation of probable errors pervades the whole book in its discussion and critical comment.

At times I have been doubtful about professional pedagogues and about standards of graduate study and of advanced degrees in education; it is a great encouragement to find a professor of education writing a seriously sustained book on statistical method in which the emphasis is not on an arithmetic system but on a mode of thinking.

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SPECIAL ARTICLES

A NEW FORM OF THE EXCLUSION PRINCIPLE IN OPTICAL SPECTRA

The question which, among the numerous quantized energy-states of an atom, will "combine," by means of a transition associated with radiation, is answered by two well-known exclusion principles, according to which such combinations occur only when the azimuthal quantum number changes by ± 1, and the inner quantum number by 0 or ± 1. In the simple spectra, such as that of sodium, these rules are closely followed, the exceptions being weak lines, produced in the presence of strong electric fields.

In the more complex spectra, the inner quantum rules are still strictly followed, but the azimuth quantum rules suffer changes. In the calcium spectrum, for example, some of the strongest lines arise from combinations between terms, both of which are of type p (Azimuth quantum 2) or of type d (Azimuth quantum 3). Professor Saunders and the writer, in a paper now in press, have advanced evidence, in favor of Bohr's suggestion, that in these "anomalous" states of the atom the two valency electrons are simultaneously shifted to states of higher energy.

A more complicated situation is found in the spectrum of titanium. Investigations of this were begun independently by Dr. and Mrs. Kiess and by the writer. When this fact was realized, it was mutually agreed that those who were first in the field should publish first, and the work of the former authors has just appeared,[1] and will be followed in due time by the writer's. The latter includes the spark spectrum as well as the arc, and brings to light combinational relations of a new type.

The arc spectrum of titanium consists of systems of singlets, triplets and quintets, of which the second is the most extensive. Terms of types s, p, d, f, g, h and i (that is of azimuth quanta 1, 2, 3, 4, 5, 6 and 7) are clearly recognizable. These terms fall sharply into two sets, such that *no two terms in the same set combine with one another,* while any term of one set combines with all terms in the other set for which the azimuth quantum differs by 0 or ± 1. In the spark spectrum, which consists of quartets and pairs, the same division into two sets exists, and, again, terms of the same set do not combine, but a term of one set may combine with any term of the other set for which the azimuth quanta differ by 0, ± 1 or ± 2—thus an f term will combine with p, d, f, g and h terms. The inner quantum rules, and Landé's other rules governing multiplet structure and Zeeman effect are completely observed. The work of Catalan, Meggers and Walters shows that substantially the same set of rules hold in the arc spectra of scandium, vanadium and iron, and the spark spectrum of the first. We have here a quite new form of the first, or "azimuthal" exclusion principle, which appears to hold good in all the more complicated spectra so far analyzed. The relations in the alkaline earths exhibit a transition between the simpler and the more complex rules. Chromium and manganese appear to represent a somewhat later stage in this transition.

It may be remarked also that in the simpler spectra the lowest energy level, or normal state of the atom, is always of small azimuth quantum number (an s term or sometimes a p term), while in the complex spectra so far studied this lowest level is a d or f term of large azimuth quantum.

These relations are likely to have important bearings on the theory of the structure of the outer parts of the atom.

Full details of the writer's work on the titanium spectrum will soon be published in a contribution from this observatory.

HENRY NORRIS RUSSELL

MOUNT WILSON OBSERVATORY,
May 16, 1924

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[1] *Journal Optical Society of America, 8,* 607, 1924.

ABSORPTION OF CARBON DIOXIDE THE FIRST STEP IN PHOTOSYNTHESIS

THE classical researches of Brown and Escombe[1] formulated in a clear and concise fashion the laws governing the diffusion of carbon dioxide through the stomata into the leaves during photosynthesis. These investigations demonstrated that the absorption of atmospheric carbon dioxide by an illuminated leaf proceeds at about one half the rate which the same surface of the leaf would possess if it were covered by a constantly renewed film of a solution of caustic alkali. "Or if we assume that the absorption of carbon dioxide in the leaf takes place only through the stomatal openings which occupy at the outside not more than 0.9 per cent. of this leaf area, we arrive at the somewhat remarkable conclusion that during assimilation the absorption per unit area of these openings must be 43 to 64 times as fast as the absorption of a unit area of a freely exposed solution of caustic alkali." Brown and Escombe dealt especially with the purely physical process of the diffusion of carbon dioxide through the stomata. The ascertainment of the agents or leaf constituents which effectuate the absorption constitutes another problem.

While the rate of photosynthesis is governed by the purely physical process of diffusion, the initial stage of the photosynthetic process must depend upon a mechanism which supplies the active centers of photosynthesis with carbon dioxide. Graham stated: "Liquid diffusion of carbonic acid is a slow process compared to its gaseous diffusion, quite as much as days are to minutes." The low partial pressure of CO_2 in the atmosphere and the relatively low solubility of the gas in water have for a long time been recognized as conditions unfavorable for photosynthesis. At 0.03 volume per cent., 1,000 cc of water dissolves at 25° 0.033 cc CO_2. 1,000 grams of *Helianthus* leaves, with an area of 3.3 square meters, contain 850 cc water and would dissolve only 0.027 cc

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[1] H. T. Brown and F. Escombe, *Phil. Trans.* Roy. Soc. B. *193,* 223 (1900).