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The Scientific Contributions of R. A. Fisher

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Abstract: This paper provides a brief description of Sir Ronald A. Fisher's scientific contributions.These were published in journals and books in statistics, genetics, biometry, agriculture, and eugenics. Included are his pioneering work in analysis of variance and covariance and multivariate statistics, as well as the following sampling distributions: product-moment correlation coefficient, regression coefficient, partial correlation, and multiple correlation. Some other findings were the Fisher Exact Test, maximum likelihood estimation, intraclass correlation coefficient, analysis of cross-classification data, Fisher Information, fiducial probability, multiple comparisons, randomization, replication, genetic findings on natural selection, and the cause of evolutionary change. Fisher provided a unified treatment of many of the important distributions involved in testing hypotheses. His controversies involving other important scientists are displayed.

Running Head: Contributions of R. A. Fisher

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The purpose of this paper is to summarize the scientific contributions of Sir Ronald Alymer Fisher, focusing especially on his work in statistics and experimental design. Connections between Fisher's scientific work and his personality are made, revealing his many controversies with other luminaries such as Karl Pearson, Jerzy Neyman, and Harold Jeffreys.

R.A. Fisher was born on February 17, 1890 in London and he died on July 29, 1962 in Adelaide, South Australia. He completed his secondary education at Harrow School in 1909, was awarded a scholarship to the University of Cambridge, and took his B.A. degree in Mathematics with honors in 1912. He was supported by an additional grant in 1913 and studied the theory of errors, statistical mechanics, and quantum theory.

In 1917 he married Ruth Eileen Guiness. They had eight children, six girls and two boys. Joan, who was the second oldest of the girls, married the famous statistician George Box, and she wrote a well-received biography of her father, R.A. Fisher: The Life of a Scientist (1978). In 1920 Ronald Fisher took the M.A. degree.

Vocationally, he worked as a Statistician at Rothamsted Experimental Station from 1919 to 1933. Karl Pearson retired in 1933, and Fisher succeeded him as Galton Professor of Eugenics at University College, London. In 1933 he also became Editor of The Annals of Eugenics. In 1943 he moved on to the University of Cambridge, where he was named the Arthur Balfour Professor of Genetics and remained there until 1957. Fisher founded the international journal Heredity in 1947 and co-edited it until his death in 1962. In 1952 he was Knighted by the Queen of England. From 1959 to 1962 he was Research Fellow, Division of Mathematical Statistics at the University of Adelaide in South Australia.

Young Ron Fisher differed from other children in two important ways. These could have influenced the way he learned. One was that his eyesight was deficient and the other was that he was precocious, the latter manifesting itself at a very young age, as demonstrated in the following anecdote when he was three (Box, 1978, pp. 12-13):

> At about this age when he had been set up in his high chair for breakfast, he asked: 'What is a half of a half?' His nurse answered that it was a quarter. After a pause, he asked, 'And what's a half of a quarter?' She told him that it was an eighth. There was a longer pause before he asked again, 'What's a half of an eighth, Nurse?' When she had given her reply there was a long silence. Finally, Ronnie looked up, a plump pink and white baby face framed with waving red-gold hair, and said slowly, 'Then I suppose that a half of a sixteenth must be a thirty-toof.'

Apparently, incidents of this sort were not irregular in the life of young Fisher. We now turn to the problem of his eyesight,which was detected later on.During his adult years, when he was a well-trained, sophisticated scientist, in solving statistical problems he made frequent use of viewing n observations as a point in n-dimensional space. That is, he found geometrical solution to statistical problems more fruitful than algebraic approaches. Some writers link this geometric ability with the fact that Fisher had poor eyesight, almost since birth. For example:

> Even in his school days his eyesight was very poor---he suffered from extreme myopia---and he was forbidden to work by electric light. In the evenings Roseveare would instruct him without pencil or paper or any visual aid. This gave him exceptional ability to solve mathematical

> problems entirely in his head, and also a strong geometric sense, which stood him in good stead later in the derivation of exact distributions of many well-known statistics derived from small samples. Other mathematical statisticians, most of whom were not very skilled algebraists, consequently found his work difficult to follow, and often criticized him for inadequate proofs and use of intuition (Yates and Mather, 1963, p.95).

The following sections of this paper are devoted to a brief description of Sir Ronald A. Fisher's scientific contributions save the next to the last section, "Controversies with Adversaries," which reveals some negative facets of his personality.

Experimental Design

R.A. Fisher's work in experimental design, which included the notion of randomization, is considered to be among the most important of his contributions to science.As well as independent group factorial designs, he invented experimental designs where restrictions on randomization are imposed, but random processes are retained. Two examples are the randomized blocks design and the Latin Square. These designs ordinarily have greater power or sensitivity than designs with independent groups. Randomization supports the internal validity of an experiment, whereas random selection protects against threats to external validity. His work on design is summarized in his book, The Design of Experiments (1960).

Randomization, replication, and blocking are the fundamental principles of experimental design introduced by Ronald Fisher. Replication is the main source of the estimate of error, while randomization insures that the estimate will be unbiased. Blocking increases precision.

Fisher provided numerous applications of statistical theory and experimental design to agriculture. "As Wishart has pointed out, the Fisherian technique 'was something in the nature of a revolution,' and altered the subsequent course of agricultural experiments throughout the world." (Mahalanobis, 1938, p. 271)

There is a great deal of controversy regarding the methods of multiple comparisons. Yet Fisher's <u>protected least significant difference</u> (LSD) is treated with respect by a number of statisticians (Huberty & Morris, 1988). It is a simple procedure. The omnibus F-test is computed first, using a specified alpha level. If it turns out to be statistically significant, pairwise tests are employed, using the same alpha level. If not, analysis is terminated.

Small Sample Theory and the Various Sampling Distributions

R.A. Fisher created the Analysis of Variance and the Analysis of Covariance. In fact, the F-ratio was named in honor of Fisher by George W. Snedecor, who at the time was at Iowa State College. These analytic techniques are very widely used in analyzing results in numerous research studies in psychology, sociology, biology, agriculture, education, medicine, business, genetics, and many other disciplines.

"The great 1925 paper already contains most of the main elements of Fisherian estimation theory: consistency; sufficiency; likelihood; Fisher information; efficiency; and the optimality of the maximum likelihood estimator." (Efron, 1998, p. 97) [This 1925 paper is: Fisher, R.A. (1925a). Theory of Statistical Estimation. <u>Proceedings of the Cambridge Philosophical Society</u>, **22**, 200-225

Ronald Fisher helped clarify the vocabulary and notation of some areas of statistical inference. The idea that one must carefully distinguish between population parameters and sample statistics was stressed by Sir Ronald Alymer Fisher. He also introduced the following features of statistical estimates---sufficiency, consistency, and efficiency---in 1922 in Philosophical Transactions.

Fisher's concept of "information" enabled estimation theory to be freed up from the large sample assumption. It should be mentioned that the leading statisticians at the turn of the 20th century, such as Karl Pearson, focused on large sample theory and analysis. In this sense, Fisher and "Student" paved the way to the development of small sample exact distributions, rather than approximations. It is important to remember that this statistical meaning of the word "information" refers only to information regarding an unknown parameter. Fisher "began with the notion that there was a precise amount of information in a sample and the proposition that it was the job of the statistician to ensure a minimal loss of information in the reduction of the data."(Box, 1978, p. 90) He developed rather complex equations for defining the amount of information in the sample and the amount of information in the estimate.

R.A. Fisher developed the randomization tests. There are two of them, one for two independent samples and one for paired observations. These are considered to be non-parametric inferential statistical tests, and, assuming normality, their assumptotic relative efficiencies (ARE), relative to their respective t-tests, are equal to 1.00, One problem with them is that the time required for the computations is unmanageable, even with the aid of computers, and the major statistical packages, such as the Statistical Analysis System (SAS) and the Statistical Package for the Social Sciences (SPSS), do not even contain routines for their computation. Computer programs written in QBASIC for calculating these statistics, when the samples are small, appear in an appendix in Siegel and

and Castellan's (1988) <u>Nonparametric Statistics for the Behavioral Sciences.</u> More generally, Fisher pioneered in nonparametrics---the sign test, exact tests in general, tests of runs, order statistics, and normal scores tests (Savage, 1976, p. 452).

Fisher corrected one segment of Karl Pearson's work on chi square, so that these tests can be evaluated with appropriate degrees of freedom. He discovered other properties of contingency table analysis including the Fisher Exact Test for 2X2 contingency tables. The latter is a useful finding as tables of this form are ubiquitous in analysis of categorical data.As Leo Goodman(1984,p. 261)has said,"Let us begin this lecture on the analysis of cross-classification data, in commemoration of Sir Ronald Fisher, by noting that this is a topic to which Fisher made important contributions at various times during a span of 40 years."

Fisher gave a rigorous proof of "Student's" result for the t-statistic, showed how it could be used to test various statistical hypotheses, and hence gave a unified treatment of practically all the important distributions involved in testing null hypotheses. He also generalized Student's result to the case of unequal variances and unequal sample sizes. There is a literature on this latter topic which is referred to as the Fisher-Behrens problem

According to Mahalanobis (1938), Fisher solved the problem of the distribution of the intraclass correlation coefficient (r).On the other hand,Cronbach(1972,p.11) claimed that "…the intraclass correlation, originally developed by Pearson, was made a part of the variance analysis by Fisher. This statistic has the same general purpose as the F-ratio of the analysis of variance. In fact, the equation linking the two is $F=[1+(k-1)r]/[1-r]$ (Box, 1978).Cronbach et al.(1972, p. 97) stated that:"The coefficient of generalizability is the ratio of universe-score variance to expected observed-score variance. This ratio is an intraclass correlation coefficient. Such correlations have appeared in various guises in earlier psychometric writings: Rulon's split-half formula, Horst's formula for reliability with multiple observations, Kuder-Richardson formulas 20 and 21, and the Hoyt-Cronbach alpha coefficient. All are intraclass correlation coefficients for one or another design." One thing Cronbach's coefficient of generalizability cannot subsume is the current approaches to consistency referred to as "precision," where one takes into account intra-individual change (Collins, 1996). "Precision" as defined by Linda Collins and her coworkers is not an intraclass correlation and is not a coefficient of generalizability.

R.A. Fisher worked out the sampling distribution of the product-moment correlation coefficient. In connection with this development, the Fisher r to Z transformation became available. The mathematical transformation per se is in reality the inverse hyperbolic tangent function. One category of application of this transformation is to test hypotheses such as $\rho = .80$, where it is necessary to deal with a negatively skewed sampling distribution. Some other categories of application are $\rho 1 = \rho 2$ and $\rho 1 = \rho 2 = \ldots = \rho k$. For the latter two cases, research workers usually assume that the samples are independent, but Fisher also provided the mathematics for the nonindependent case. He also found distributions for mean square error, the regression coefficient, the partial correlation, and the multiple correlation coefficient. The error terms mentioned above are not the same as the error variance in psychometric theory.

Sir Ronald A. Fisher proved certain properties of discriminant function analysis, a multivariate statistical technique, and, for the two group case, he showed a mathematical link between it and multiple regression. "Discriminant analysis begins with the scores of a sample of examinees for whom the correct classifications are known. These scores are used to calculate weights for combining the variables into a new variable that will eventually be used to classify examinees for whom the correct classifications are unknown." (Crocker and Algina,1986, p. 257)In multiple regression,the constructed equation is used to predict scores for future examinees, whereas for discriminant analysis, the equation developed is used to classify future examinees. Fisher made a number of contributions to multivariate statistics. For further details, see T.W. Anderson's (1996) "R.A. Fisher and Multivariate Analysis," which appeared in Statistical Sciences.

Probability

Fisher introduced the idea of fiducial probability. Here one wants an interval rather than a point estimate. Today the theory of confidence intervals of Neyman and Pearson is advocated by most statisticians and little attention is paid to Fisher's fiducial probability. For one thing, the approach of the former is usually more powerful, which means it produces more narrow confidence intervals.

Fisher proved certain properties of the maximum likelihood estimator and used them widely in his research.In employing the maximum likelihood estimator, one selects as an estimator of a parameter that value which will maximize the likelihood of the sample that is actually observed to occur. Early on he had no use for Bayesian estimators, but later, partly due to the influence of the Bayesian luminary, Harold Jeffreys, he reversed his position. Twenty years after the great controversy between Fisher and Jeffreys, Runcom recalls that "Fisher was genial and Jeffreys was friendly. I remember saying something about their controversy and, in his charming way, Fisher said, 'He agreed with Jeffreys approach more than the current school of Neyman,' and Jeffreys very emphatically said, 'Yes, we are closer in our approach.'" (Box, 1978, p. 441)

Population Genetics, Evolutionary Theory, and Eugenics

> Fisher's work in genetics was comparable in importance to his purely statistical contributions and equally reflected his originality and independence of outlook. In the first decade of the 20th century, Mendelian genetics was still a new subject. And its quantitative consequences were not yet properly appreciated. It was in dispute whether they were consistent with Darwin's theory of evolution by natural selection. (Bartlett, 1968, p. 490)

Fisher developed a mathematical theory on the basis of extant genetic research to establish the principle of natural selection, on a more rigorous basis than Darwin had claimed, as the cause of evolutionary change. This work and related matters are detailed in his book, The Genetical Theory of Natural Selection. (1930)

The science of Eugenics deals with the improvement of hereditary qualities of a race or breed and especially of human beings. In its early stages of development it was not related to racism. At the encouragement of Leonard Darwin, who was the second youngest of Charles Darwin's five sons, Ronald Fisher began to write reviews, mostly of books and journals in biology, for the quarterly journal published by the Eugenics Society, Eugenics Review. During a two decade span of time, from 1914 to 1934, Fisher produced 200 such reviews for publication in this journal. During much of this time interval, Leonard Darwin was president of the Eugenics Society and Fisher was honorary secretary. (Bennett, 1983, p. 15)

Controversies with Adversaries

Early in R.A. Fisher's scientific career, his attitude toward Bayesian probability and

Bayesian inference was highly negative. At the time, the most prominent Bayesian since the Reverend Thomas Bayes was Harold Jeffreys. Hence they were natural enemies. "In conversation, Fisher dismissed Harold Jeffreys' book, Theory of Probability, with the words, 'He makes a logical mistake on the first page which invalidates all the 395 formulae in his book.' Jeffreys' 'mistake' was to adopt Bayes' postulate." (Box, 1978, p. 441)

But Fisher moved closer to Jeffreys' philosophical position as the years passed, perhaps, in part, to distance himself from the relative frequentist view of Jerzy Neyman. Sir Edward Bullard recalled that "… the feud between Jeffreys and Fisher had ended on the day they both went to hear Arthur Eddington talk on the nature of scientific inference, and were so horrified that they shook hands and promised not to write any more rude things about each other." (Box, 1978, p. 442)

The reader interested in Ronald Fisher's philosophy of science should consult Nancy Brenner-Golomb's chapter entitled, "Fisher's Philosophical Approach to Inductive Inference," in Keren and Lewis's (Eds.) A Handbook for Data Analysis in the Behavioral Sciences: Methodological Issues (1993).

"Slight, bearded, eloquent, reactionary, and quirkish, Fisher made a strong impact on all who met him. The geniality and generosity with which he treated his disciples was complemented by the hostility he aimed at his dissenters. His mastery of the elegantly barbed phrase did not help dissolve feuds." (Gridgeman, 1972, p. 7)

"The recurrence of feuds . . .was by now beginning to be as much a manifestation of Fisher's own temperament as of his antagonists. His wide interests and strong personality made him a charming and lively companion when he chose to be and a generous colleague to those who were in simpathy with his work, as many have testified. But his emotions as well as his intellect were too bound up in his work for him to tolerate criticism, to which he replied in vigorous and sometimes quite unfair terms." (Bartlett,1968, p. 487)

Two medical doctors, Raymond Doll and Bradford Hill, published a paper entitled, "Smoking and Carcinoma of the Lungs: Preliminary Report," in 1950 in the British Medical Journal. Their findings, which were based on non-experimental (i.e., observational) studies, seemed to imply that smoking causes lung cancer.They attempted to make their field observations resemble an experiment by controlling for certain variables such as gender, age, and general physical health. Fisher attacked them in print and in speeches, indicating that only (true) experimental designs are capable of establishing empirical causality.

"Fisher raised the issue of association versus causation that clouds the interpretation of any observational study. In his famous constitutional hypothesis, he suggested that the smoking and lung cancer association could be explained by the confounding effects of a genotype that predisposed both to smoking and lung cancer. Data on twins were used to substantiate his assertions that smoking behavior was influenced by genetics." (Breslow, 1996, p.15)

"Fisher's extreme viewpoint is best understood by recalling that he was both geneticist, well aware of the influence of heredity on disease, and the statistician, who had perfected randomization as the method for drawing causal conclusions in experimental settings….He also took sharp exception to what he regarded as the hysterical reaction of the public media to an unproven hypothesis." (Breslow, 1996, p. 24) Fisher's point in this last sentence is defensible. Also, focusing on the genotype could be useful in this and other studies for detecting interactions.

"Today, the fact that smoking causes lung cancer and many other cancers is widely accepted, and cancer studies that fail to control for smoking status are open to criticism." (Gail, 1996, p. 6)

R.A. Fisher's arguments on these issues might have been more receptive to the medical profession and other scientists if it hadn't been for the fact that at the time he was serving as a consultant to a tobacco industry..

The following paper by Jerome Cornfield (1951), " A Method of Estimating Comparative Rates from Clinical Data: Applications to Cancer of the Lung, Breast, and Cervix" which appeared in The Journal of the National Cancer Institute, is credited by many with issuing in the modern view of defensible case-control studies.

We next turn to Ronald Fisher's relation with his two "mortal enemies," Karl Pearson and Jerzy Newman. First, several direct quotations from Fisher's book, Statistical Methods and Scientific Inference (1959), are presented as follows:

"This proposal, which has perhaps now been abandoned (though at the time an equally faulty proposal was quickly put forward by Newman)." (Fisher, 1959, p. 98)

It , , , "was put forward by J. Neyman as a general solution of the problem. That 'solution' also has never, I believe, been applied in practice." (Fisher, 1959, p. 100)

The following quotation refers to Egon Pearson, the son of Karl Pearson. "A misconception having some troublesome consequences was introduced by Neyman and Pearson in 1933, shortly after they had learnt of the possibility of deriving probability statements and therefore limits of significance by the fiducial argument." (Fisher, 1959, p. 102)

"It is to be feared, therefore, that the principles of Neyman and Pearson's 'Theory of Testing Hypotheses' are liable to mislead those who follow them into much wasted effort and disappointment , and that its authors are not inclined to warn students of these dangers." (Fisher, 1959, p. 89)

"The terrible weakness of [Pearson's] mathematical and scientific work flowed from his incapacity in self-criticism and his unwillingness to admit the possibility that he had anything to learn from others, even in biology, of which he knew very little. His mathematics, cosequently, though always vigorous, were usually clumsy, and often misleading. In controversy, to which he was much addicted, he constantly showed himself to be without a sense of justice." (Fisher, 1959, p. 3)

"Indeed, the two leading statisticians in England at the beginning of the twentieth century, K. Pearson . . . and F.Y. Edgeworth . . .both put forward attempts, discordant indeed and both abortive, to justify the mode of reasoning in which no doubt each had been brought, but what had since been discredited." (Fisher, 1959, pp. 34-35)

Now why was Fisher so vicious and vindictive to Karl Pearson and Jerzy Neyman? An interaction was involved. Of course, it was partly due to Fisher's temperament But also, as we shall see, both of these other scientists manifested behaviors which triggered Fisher's ire. Pearson recognized that Fisher was talented and he offered him a job in his lab. The position was defined, however, so that Pearson would dictate the research program which must be followed and he would also determine exactly what academic courses would be taught by Fisher. Joan Fisher Box (1978, p. 61) referred to it as a castrating type job offer. Luckily, Fisher had the courage to reject Pearson's offer and to instead take a position at Rothamsted Experimental Station, where he could create his own research program. In general, Pearson acted somewhat aloof to R.A. Fisher. And when Fisher submitted a manuscript to him for possible publication,Pearson rejected it without providing a plausible reason. Fisher stated that he would never again submit a manuscript to Pearson, and he never did. It was well-known that Karl Pearson would allow nothing to be published which was inconsistent with his views or for which he personally could not find time to read.

Although Pearson created the chi square goodness of fit test, there were errors in his work due to his lack of knowledge of the concept of degrees of freedom. Fisher made corrections in Pearson's work, mounting a vicious personal attack on Karl Pearson. "Nobody could mistake the butt of Fisher's attack, and the matter could hardly have been more calculated to upset Pearson. Pearson had introduced the chi square test more than 20 years before and from that time had been its chief interpreter. Now he was told, in effect, that he did not understand the primary principles of its application, that he had misled his followers and spread his own confusion. (Box, 1978, p. 85)

Pearson retaliated by blocking another potential publication by Fisher. He did this by intimidating the editors of <u>The Journal of the Royal Statistical Society</u>. They rejected a submission by Fisher with no explanation. Karl Pearson, at the height of his powers, was a highly respected and formidible figure in academia.

"In 1934 Jerzy Neyman joined [Karl] Pearson's staff. At that time there was no ill-feeling between him and Fisher, indeed Neyman had applied to Fisher as well as Pearson when he was looking for a job in England. . . .The situation changed rapidly thereafter. Neyman sniped at Fisher in his lectures and blew on the unquenched sparks of misunderstanding between the departments with apparent, if undeliberate, genius for making mischief." (Box, 1978, pp. 262-263)

"The conflict between Neyman and Fisher was primarily conditioned by their different approach to the whole subject. Fisher was a research scientist using mathematical skills; Neyman a mathematician applying mathematical concepts to experimentation. Now, mathematicians did not readily accept the role of randomization in Fisher's statistical theory." (Box, 1978, p.265)

In Ronald Fisher's fiducial probability approach, the parameter to be estimated is viewed as a variable, whereas in the relative frequency approach of Jerzy Neyman and Egon Pearson, the parameter is a constant and the sample estimates made vary about this true value. Hence they construct confidence intervals and can express what proportion of the intervals will contain the parameter. This latter procedure is the one that appears in current day textbooks and Fisher's method has fallen into disuse. Efron has indicated that "…the fiducial distribution [is] generally considered to be Fisher's biggest blunder." (1998, p. 105)

"Newman's approach, however, was entirely original and very characteristic. As in the theory of hypothesis testing, it was 'the best'---optimality--- which he sought. In this situation he proceeded to formulate as 'the best' the confidence interval that has the smallest probability of containing any false values. He was then able to take all the concepts and results from the theory of best tests (unbiasedness, uniformly most powerful, and so on) and translate them into corresponding ones in the theory of estimation. It was a formidable unification." (Reid, 1982, p. 134)

Florence N. David, who was a research assistant to Karl Pearson during the early 1930s, provides us with some insight regarding the statistical luminaries of that time period. "I saw the lot of them. Went flyfishing with Gosset. A nice man. Went to Fisher's seminars with Cochran and that gang. Endured K.P. Spent three years with Neyman.

Then I was on Egon Pearson's faculty for years.

"Fisher was very vague. Karl Pearson was vague. Egon Pearson vague. Neyman vague. Fisher and Neyman were fiery. Silly! Egon Pearson was on the outside.

"They were all jealous of one another, afraid somebody would get ahead. Gosset didn't have a jealous bone in his body. He asked the question. Egon Pearson to a certain extent phrased the question which Gosset had asked in statistical parlance. Neyman solved the problem mathematically. (Reid, 1982, p. 133)

Sir Ronald A. Fisher's Publications and Honorary Awards

According to Bradley Efron, "Fisher is the single most important figure in 20th century statistics," (1998, p. 95)

He wrote some 300 papers and seven books throughout his prodigious career. In addition to his two books on experimental design and genetics which we have alluded to, he produced Statistical Methods for Research Workers (1925b), for which a nymber of editions appeared subsequently, some of them in French, German, Italian, Japanese, Spanish, and Russian. His published journal articles have been packaged in five volumes and are titled Collected Papers of R.A. Fisher (Bennett, 1971). There are 294 papers in all and their publication dates range from 1912 to 1962, covering a span of one-half century. A preface to these volumes, authored by Yates and Mather, appeared originally in Biographical Memoirs of Fellows of the Royal Society of London (1963).

In 1938, the first edition of Statistical Tables for Biological, Agricultural, and Medical Research, by Fisher and Yates, was published. Shewart edited Fisher's Contributions to Mathematical Statistics, which appeared in 1950. P.C. Mahalanobis wrote a brief biographical sketch for this volume which he published earlier in Sankhya (1938). What is unique about this work is that R.A. Fisher chose 43 of the articles he felt were most important to include in this volume. Furthermore, for each paper he wrote an annotation and described the context in which the paper was written. It may be of interest to note that Mahalanobis was the founder of Sankhya and he made important contributions to discriminant function analysis as well as to many other areas in theoretical and applied statistical inference. Ronald Fisher's book on The Theory of Inbreeding was published in 1949.

"He received many honors and awards: the Weldon Memorial Medal (1928), the Guy Medal of the Roral Statistical Society in gold (1947), three medal of the Royal Society, the Royal Medal (1938),the Darwin Medal (1948),and the Copley Medal (1956);honorary doctorates from Ames, Harvard, Glasgow, London, Calcutta, Chicago, the Indian Statistical Institute, Adelaide, and Leeds. He was Foreign Associate, United States National Academy of Sciences; Foreign Honorary Member, American Academy of Arts and Sciences; Foreign Member, American Philosophical Society; Honorary Member, American Statistical Association; Honorary President, International Statistical Institute; Foreign Member, Royal Swedish Academy of Sciences; Member, Royal Danish Academy of Sciences ; Member, Pontifical Academy; Member, Imperial German Academy of Natural Science; He was created Knight Batchelor by Queen Elizabeth in 1952." (Box, 1983, p. 109) Fisher also served as president of the Royal Society from 1952 to 1954.

Concluding Comments

This paper has displayed the impressive intellectual versatility of Sir Ronald A. Fisher, focusing not only on his contributions to statistics and other quantitative disciplines and on experimental design, but also on biology, population genetics, evolutionary theory, eugenics, agriculture and Darwinism. His research "on discriminant function analysis . . . is now used in such areas as weather forecasting, medical research, and educational testing." (Hall, 1995, p.646)

It should also be mentioned that Fisher visited the United States from time to time to give invited lectures and to teach courses in statistics, experimental design, and related topics. "During a 1936 summer lectureship at Iowa State College's agricultural research center at Ames (were he had also taught during the summer of 1931) Fisher established contacts that helped popularize his techniques among American educators and psychologists, as well as agriculturalists." (Hall, 1995, p 646)

"In appraising Fisher's work, one must consider, in addition to [the] general boundaries that demarcate it, his occasional specific errors and, more importantly, his temperamental bias in controversy. Fisher's scientific achievements are, however, so varied and so penetrating that such lapses cannot dim their luster or reduce his ranking as one of the great scientists of this [i.e., the twentieth] century." (Bartlett, 1968, p. 491)

"Fisher burned even more than the rest of us, it seems to me, to be original, right, important famous, and respected, and in enormous measure, he achieved all of that, though never enough to bring him peace." (Savage, 1976, pp. 445-446)

"Even scientists need their heroes, and R.A. Fisher was certainly the hero of 20^{th} century statistics. His ideas dominated and transformed our field to an extent a Caesar or an Alexander might have envied." (Efron, 1998, p. 95)

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