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Selected Works of E. L. Lehmann

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Springer

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Preface to the Series

Springer's Selected Works in Probability and Statistics series offers scientists and scholars the opportunity of assembling and commenting upon major classical works in statistics, and honors the work of distinguished scholars in probability and statistics. Each volume contains the original papers, original commentary by experts on the subject's papers, and relevant biographies and bibliographies.

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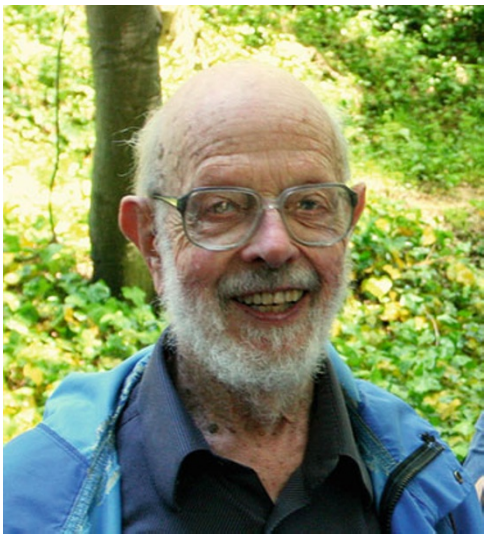
The subjects of the volumes have been selected by an editorial board consisting of Anirban DasGupta, Peter Hall, Jim Pitman, Michael Sörensen, and Jon Wellner.



Preface

Erich L. Lehmann's legacy is profound and extensive. His scholarly contributions, as partially presented and commented upon in this volume of selected works, clearly demonstrate his broad interests and the widespread impact that his "system building" life-long work had on the discipline. Stephen Stigler (2009), writing about Erich's honorary degree from the University of Chicago, states that the citation on Erich's degree read as follows:

> *Your research on the application of decision theory to statistical problems has helped create and organize modern mathematical statistics; your elegant treatises have guided the curricula of a majority of the nation's graduate programs and given shape to the discipline, and your teaching has inspired a generation of scholars.*

The present collection of selected papers shows Erich's multifaceted contributions. His work on concepts of dependence in 1966 has created a substantial literature and continues to have a large impact on applied probability. His joint work with Joseph L. Hodges on the efficiency of rank tests, and the corresponding work on efficiency of estimators derived from rank tests, helped to assuage the fears of the nonbelievers of nonparametric methodologies. The Lehmann alternatives, with its implicit connection to the proportional hazards model of Cox, and its spillover into the modeling of ROC curves literature, has been used both in the applied and theoretical statistical camps. Erich's work on unifying concepts, ideas, and results in decision theory under an overarching structure hinged on his use of concepts of unbiasedness and invariance applied in the context of exponential and group families of distributions, a literature to which he contributed substantially and extensively. In this regard, Erich's role was one of a system builder. But he also found himself as the originator of ideas in a very substantive way. One example is a concept that serves as one of the main pillars of the statistical decision theory of Wald. Wald, in his book Statistical Decision Functions (1950), on page 29 credits Erich with the concept of a complete class. Here is the exact text:

> *The concept of a complete class of decision functions was introduced by Lehmann, and the first result regarding such classes is due to him [30]. . . .*

Wald then proceeds to discuss the first result on complete classes proved by Erich. The citation [30] refers to Erich's "On Families of Admissible Tests" published in the the *Ann. Math. Stat.* in 1947.

Erich's books, translated into several languages, continue to have a large impact on the education of the next generations of statisticians. His enjoyment for teaching one-on-one is reflected in the large number of Ph.D. students that he mentored.

Erich also served the broader statistical community well. He was Editor (1953-1956), and Associate Editor (1956-1968) of the Annals of Statistics. He served as President of the Institute of Mathematical Statistics (1960-1961) and chaired the Department of Statistics at Berkeley (1973-1976). He was a member of committees of visitors to the department of statistics at Harvard (1974-1980) and Princeton (1975-1980) Universities.

Many honors were bestowed upon him. Among others, there are the following: Guggenheim Fellow (1955-1956, 1966-1967, 1980-1981); Research Professor, Miller institute for Basic Research (1962-1963, 1972-1973); IMS Wald Memorial Lecturer (1964); Elected to the American Academy of Arts and Sciences (1975) and to the National Academy of Sciences (1978); He received honorary degrees from the University of Leiden (1985) – this was the first honorary degree awarded by Leiden to a mathematician since 1884 when Stieltjes received it. An honorary degree from the University of Chicago followed in 1991; He was elected Honorary Fellow of the Royal Statistical Society (1986) and was the COPSS R. A. Fisher Memorial Lecturer (1988); He received the American Statistical Association (ASA) Wilks Memorial Award, and he was the first ASA Goffried Noether Awardee and lecturer. Posthumously, he received the 2009 best paper award from the Journal of Nonparametric Statistics.

In addition, Erich's gentle and unselfish spirit and mentorship did not go unnoticed by his students who organized several meetings in his honor and published collections of works related to Erich's interests. These include: A Festschrift for Erich L. Lehmann (1983), and four Erich L. Lehmann Symposia on optimality (2002, 2004, 2007 and 2011).

In planning this volume, Erich and I met several times to decide on the organization of the papers into the various chapters, and who the contributors would be. Clearly, the chapters cannot be defined sharply as there are papers that could very easily have been placed in a different group. The careful reader will notice two surprises in the collection. The first one is easy to detect. Sections 3.10 - 3.12 of *Testing Statistical Hypotheses* 1959, are being included here. This is happening thanks to Lawrence D. Brown who suggested, and Erich agreed, that they should be reproduced here.

The second pleasant surprise is the inclusion of Erich's work on the history of confidence statements (1958). Stephen Stigler was kind enough to point out this paper to us.

I would like to thank Jim Pitman for his patience and encouragement during the preparation of this volume. John Kimmel and Eric Strauss have been very supportive of this project. Thanks also go to the contributors to this work. The requests for contributions, as it always happens, came at a busy time for everyone. The contributors' special efforts in helping to bring this project to fruition is greatly appreciated.

My deep gratitude goes to Juliet Shaffer. Julie was a great source of information during the preparation of this work. In addition, the many invitations to join her and Erich for lunch or dinner, were great opportunities to get to know them better. Erich's and Julie's concern for my family will always be appreciated.

Erich Leo Lehmann passed away in the early morning of September 12^{th}, 2009. I first learned of his death as I waited for my wife at the Oakland airport so that, together, we could visit Erich – but it was not to be. I and my family were very fortunate to get to know Erich and enjoy his and Julie's company. Erich will always be in our thoughts.

Houston, TX Javier Rojo

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Erich Leo Lehmann

Erich Leo Lehmann was born in Strasbourg on November 20^{th}, 1917. The year of 1917 was a turbulent year. The Mexican revolution was coming to a close while the Bolshevik revolution had just started, and World War I, although ending short of one year after Erich's birth, was still ravaging Europe. Strasbourg was part of Germany at that time, and Erich's father was stationed there as part of the German army to which he had been drafted and now served in his capacity of Captain. At two months of age, the family moved to Frankfurt. Erich was raised in Germany but with the coming of the Nazis to power in 1933, the family moved to Switzerland. Erich stated in DeGroot (1986) that: "After some wondering, because I had a brother who was dying and needed to be cared for first, we settled in Switzerland." One aspect of his education in Germany, however, would come to play a very important role in his future. Erich felt that his strong respect for authority was a direct consequence of his being raised in Germany. Thus, although his dream was to study German literature, given the conditions in Germany at the time, his father suggested mathematics for which Erich had shown affinity. Erich accepted the advice without much resistance. After consulting with the mathematician Edmund Landau, and Landau having assessed, and been satisfied with, Erich's mathematical ability, Erich studied mathematics for five years in Zürich. In 1938, feeling that Switzerland was not a good place for a German refugee, and seeking Landau's advice once more, Erich enrolled in Trinity College in Cambridge. After two years in Trinity College, and not having adjusted well to the environment there, together with the threat of a German invasion of England, Erich traveled to the United States on a French visa under the French quota. Traveling under the French quota was possible since the Treaty of Versailles had returned Strasbourg to France in 1919. The 1924 Immigration Act, also known as The Johnson-Reed Act, provided for a quota of two percent of the total number of people of each nationality in the United States as of the 1890 national census. The Act was revised by Congress in 1952. Erich arrived in New York in November of 1940. He had with him a letter of introduction for Richard Courant from Landau's wife. Courant recommended Berkeley as a good place, a growing and upcoming university.

Erich arrived in Berkeley on January 2^{nd} of 1941. Not having completed a B. A. in Europe, he was admitted as a probationary graduate student in the mathematics

department by Griffith C. Evans who was the chair of the mathematics department at the time. Some time later, Evans advised Erich that it was perhaps best to look for an area with more application to the war effort and he suggested physics or statistics as a better choice than mathematics. Erich chose statistics over physics and, after speaking with Neyman, started taking classes in statistics. However, the course material was not particularly to Erich's liking and he decided to go back to mathematics. Before he was able to gather the courage to speak to Neyman and Evans about his plans, Neyman offered him a job, and he accepted. This stage of Erich's life is vividly and amusingly recounted in DeGroot (1988): "So three times: First, German literature – my father says do mathematics. Second, I try to do mathematics and Evans says do something applied. The third time, I want to go back to pure mathematics and Neyman says here's a job for you". One may also want to include a fourth occasion when Erich followed advice. Namely when Landau recommended Trinity College in Cambridge.

In 1942, Erich was granted the M. A. degree from the University of California at Berkeley. After a hiatus of roughly a year, from the spring of 1944 to August of 1945 when Erich was stationed in Guam working as an Operations Analyst for the Air Force, Erich returned to Berkeley and started work on his thesis. In preparing to write up the results, a citation of related work led to other works that, painfully, led to the realization that Erich's work was already part of Markov's, and other Russian probabilists' work. This created a difficult situation for Erich, specially since Neyman was going away as a supervisor in the Greek elections. Neyman then asked Pao-Lu Hsu, who had been his student in London in 1938 and who was visiting Berkeley for the 1945 fall term, to give Erich a new thesis topic. Hsu proposed a problem on which he had been working and for which he had already obtained independent results. Erich learnt about Hsu's generosity some time later and wanted to thank him personally after Hsu, as Neyman was hoping, returned to Berkeley from his one-semester visit to Columbia. But Hsu never returned to Berkeley having gone from Columbia to North Carolina and then back to China. Erich, however, always remained grateful for Hsu's generosity. With both Neyman and Hsu gone, Neyman asked George Polya at Stanford to supervise Erich's thesis. Weekly or biweekly meetings with Polya, commuting between Berkeley and Stanford, eventually led to Polya urging Lehmann to write up the results in preparation for finishing. It turned out that Neyman was able to return in time to be part of the examination.

Erich was offered a faculty position in 1946 at Berkeley and, despite offers from Stanford in 1951 and from the Eidgenössische Technische Hochschule (ETH), the Swiss Federal Institute of Technology, in 1959, Erich never left Berkeley. Some notable exceptions were the visits to Columbia and Princeton during the 1950-1951 academic year, a one year visit to Stanford during the 1951-1952 academic year to allow more time for the unrest created by the Loyalty Oath to die out, and a stay in Princeton from 1995 to 1997 after Julie accepted a position as principal research scientist and coordinating director of the Large Scale Assessment Group, and Erich served as distinguished research scientist at the Educational Testing Service.

Erich returned to Berkeley from Stanford in 1952 as an Associate Professor of Mathematics, and in 1954 was promoted to Professor of Mathematics. In 1955, after

Neyman succeeded in creating a separate department of statistics, Erich's title changed to Professor of Statistics. In 1988, Erich retired and became Professor Emeritus.

Throughout his prolific career, Erich, who as a teenager had dreams of becoming a writer, wrote several influential textbooks. Some of these have been translated to several languages. The books, *Testing statistical hypotheses* (first edition, 1959; second edition, 1986; third edition, with Joseph P. Romano, 2005 – the first edition has been translated into Russian, Polish, and Japanese), and *Theory of Point Estimation*, (first edition, 1983; second edition with George Casella, 1998 – the first edition was translated into Russian, and the second into Chinese), continue to have impact in preparing the next generations of professional statisticians. Together with *Nonparametrics: Statistical Methods Based on Ranks* – first published in 1975, then in paperback in 1998, and then by Springer Science + Business Media, LLC in 2006, and translated into Japanese, these three books have been cited more than 7,500 times according to the ISI Web of knowledge. And the number of citations keeps increasing. Other books include: *Basic Concepts of Probability and Statistics*, with Joseph L. Hodges; *Elements of Finite Probability*, with Joseph L. Hodges; *Elements of Large-Sample Theory*; and *Reminiscences of a Statistician: The Company I Kept*.

In addition, Lehmann was a *Special Editor* for the second edition of *Statistics: A Guide to the Unknown*, edited by Judith M. Tanur. For the third edition, published in 1989, Judith M. Tanur was the editor while Lehmann continued as a co-editor. Two more works, *Statistics: a guide to the study of the biological and health sciences* and *Statistics: a guide to political and social issues*, both published in 1977, were a result of these collaborative efforts. Lehmann was a *Special Editor* for the latter and a co-editor for the former.

Among his many influential papers, Erich seemed to have a special liking for "The power of rank tests", *Ann. Math. Statist.*, Vol. 24, pp. 23-43, 1953, and for "The efficiency of some nonparametric competitors of the t-test", *Ann. Math. Statist.*, Vol. 27, pp. 324-335, 1956. In the former, Erich introduced a set of alternatives for which calculating the power of rank tests against the usual alternatives in the two-sample problem is simplified. This set of alternatives is now known as *The Lehmann alternatives*. In the latter paper, co-authored with Joseph L. Hodges, it is shown that the asymptotic relative efficiency (ARE) of the two-sample Wilcoxon test, relative to the t-test, is never under .864. This assuaged the anxiety of the doubtful who feared that nonparametric techniques had very little power. These results were later extended to the problem of estimating a location parameter in "Estimates of location based on rank tests", *Ann. Math. Statist.*, Vol. 34, pp. 593-611, 1963, where it was shown that the ARE of the estimates obtained from rank tests to the classical linear estimates agrees precisely with the ARE of the rank tests to the corresponding t-tests. Another paper that continues to have impact on applied probability is the paper "Some concepts of dependence", *Ann. Math. Statist.*, Vol. 37, pp. 1137-1153, 1966. According to the ISI web of knowledge, the paper has been cited at least 540 times, with at least 20 of these citations occurring in the first six months of 2011.

Erich chaired the statistics department at Berkeley from 1973-1976, and also served the broader statistical community as Editor (1953-1955) and Associate Editor (1955-1968) of the Annals of Mathematical Statistics, President of the Institute

of Mathematical Statistics 1960-1961, and as a member of committees of visitors to the departments of statistics at Harvard (1974-1980) and Princeton (1975-1980) Universities.

During his lifetime, Erich received many accolades for his contributions. He was a three-time Guggenheim Fellow (1995-1956, 1966-1967, and 1980-1981) and a two-time Miller Institute for Basic Research Professor (1962-1963 and 1972-1973). He gave the IMS Wald Lectures in 1964, and the COPSS R. A. Fisher Memorial Lecture in 1988. Surprisingly, he was never invited to deliver the IMS Neyman Lecture. In 2000, he became the first recipient of the ASA Goffried Noether Award, and he received the Journal of Nonparametric Statistics Award for best paper in 2009. He was elected to the American Academy of Arts and Sciences in 1975 and, in 1978, became an elected member of the National Academy of Sciences. He received Dr. *honoris causa* degrees from the University of Leiden in 1985 and from the University of Chicago in 1991. The former was the first Dr. h. c. awarded to a mathematician at Leiden in a century, Stieltjes having been the last mathematician to receive it in 1884. Erich wrote about this experience in Lehmann (2008). In addition, there was a *Festschrift for Erich L. Lehmann* organized by Bickel, Doksum, and Hodges in 1982, and a series of *Lehmann Symposia*, organized by Rojo and Perez-Abreu in 2002, and Rojo in 2004, 2007, and 2011. Although he did not like teaching large classes, he acknowledged that the one-on-one interaction with his Ph.D. students, of whom he had 43+, was the most rewarding aspect of teaching.

Erich Leo Lehmann died on the morning of September 12^{th}, 2009. At the time of his death, he was working on the manuscript for the book *Fisher, Neyman, and the Creation of Classical Statistics*, soon to be published by Springer-Verlag. After his death, Erich's life and work were celebrated with a memorial service on the Berkeley campus on November 9, 2009. In addition, the statistical community he appreciated so much honored him with a memorial session, organized by Peter Bickel, at the joint statistical meetings in Vancouver, Canada on August of 2010; a lecture by Peter Bickel at the IX Latin American Congress in Probability and Mathematical Statistics meeting in Venezuela in November of 2009; and a memorial session, organized by Willem van Zwet, during the IMS meeting in Sweden during August of 2010.

Several obituaries have been published that shed light on Erich's work and life. See, for example, Brillinger (2010), and Bickel (2009). The papers by Stigler (2009) and Rojo (2009) provide accounts of some of Erich's experiences.

Outside statistics, Erich loved music and Franz Schubert was one his favorite composers. He also enjoyed playing the piano and entertaining visitors at his home. He derived enormous pleasure from family life. While working with Erich on the planning of this collection of works, I once asked him what were the aspects of his life that he found the most rewarding. Immediately, and without hesitation, he responded "my children, grand-children, and great-grand-children and having met Julie".

Houston, TX Javier Rojo

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