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ERICH LEO LEHMANN—A GLIMPSE INTO HIS LIFE AND WORK

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Through the use of a system-building approach, an approach that includes finding common ground for the various philosophical paradigms within statistics, Erich L. Lehmann is responsible for much of the synthesis of classical statistical knowledge that developed from the Neyman–Pearson–Wald school. A biographical sketch and a brief summary of some of his many contributions are presented here. His complete bibliography is also included and the references present many other sources of information on his life and his work.

1. Biographical sketch. Erich L. Lehmann was born in Strasbourg on November 20th, 1917. He passed away in Berkeley, California on the morning of September 12th, 2009. His family left Germany in 1933, as the Nazis came to power, to settle in Switzerland. He spent five years in Zürich and two years in Trinity College in Cambridge studying mathematics. Under the United States French immigration quota—Strasbourg was, by then, part of France as a consequence of the Versailles treaty—he arrived in New York at the end of 1940. Edmund Landau, the famous number theorist, was an acquaintance of the Lehmann family and had suggested Trinity College as the place Erich should go to study mathematics. Landau died in 1938 from a heart attack, but his wife wrote a letter of introduction for Erich to take to Landau's Göttingen colleague Richard Courant who was now in New York developing what became the Courant Institute. Courant, having offered the option to "live in New York or in the United States," and Erich having opted for the latter, recommended the University of California as an up-and-coming good place. Erich arrived in Berkeley, California in January 1, 1941.

Erich's first order of business was to speak with Griffith C. Evans, chair of the mathematics department, who immediately accepted him as a probationary graduate student. The probationary status resulted from Erich not having a degree. Evans, who had been recruited from the mathematics department at Rice Institute—now Rice University—had a broad vision for mathematics and had the intention of hiring Ronald A. Fisher, whom he knew. However, a visit by Fisher

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to Berkeley did not go well. The news of Jerzy Neyman's successful visit to the United States, culminating with a set of lectures at the U.S. Department of Agriculture, reached Evans who in 1937 offered Neyman a job in the mathematics department at the University of California without having met him. With the advent of the second world war, Evans advised Erich that it might be a good idea to move from mathematics to some other area—perhaps physics or statistics—that could be more useful to the war efforts. Erich, not being fond of physics, opted for statistics. His initial experiences, however, led him to second-guess his decision. In Lehmann (2008B), Erich writes that "statistics did not possess the beauty that I had found in the integers and later in other parts of mathematics. Instead, ad hoc methods were used to solve problems that were messy and that were based on questionable assumptions that seemed quite arbitrary." (Hereafter, a reference followed by "B" indicates book reference in Section 9; a bracketed reference [x] refers to that numbered reference in Section 8; other references appear at the end of this work.) After some soul-searching, he decided to go back to mathematics and approached the great logician Alfred Tarski. Tarski accepted him as a student, but before Erich had an opportunity to let Evans and Neyman know about his decision, Neyman offered him a job as a lecturer with some implicit potential for the position to become permanent. Feeling that this represented a great opportunity to become part of a community, something that Erich very much desired at that point in time, he decided to take the offer and abandoned his plans for returning to mathematics. In 1942 Erich received an M.A. degree in mathematics, and was a teaching assistant in the Statistical Laboratory from 1942 to 1944 and from 1945 to 1946.

These early years as a graduate student and a teaching member of the department—while sharing office space with Charles Stein, Joseph Hodges and Evelyn Fix—helped to forge lifetime friendships and productive collaborations. After he spent the year from August 1944 to August 1945 stationed in Guam as an operations analyst in the United States Air Force, Erich returned to Berkeley and started working on a thesis problem proposed by Pao-Lu Hsu in consultation with Neyman. The problem was in probability theory—some aspect of the moment problem—and after obtaining some results and getting ready to write them up, Erich discovered that his results were already in Markov's work. The situation became complicated as Neyman was invited to supervise the Greek elections. Before leaving, Neyman asked Hsu if he could provide another thesis topic for Erich. Hsu obliged but was not able to supervise Erich's thesis, as he followed Hotelling from Columbia to North Carolina and then decided to go back to China. Neyman turned to George Pòlya at Stanford for help. Weekly meetings with Pòlya, commuting between Berkeley and Stanford, finally yielded a thesis. Meanwhile, Neyman was back from Greece after being relieved of his duties for insubordination. Neyman had felt that the elections were rigged and decided to check by himself. When asked to stop, he refused. This turn of events allowed Neyman to be back in Berkeley for Erich's examination. Thus, in June of 1946, Erich obtained his Ph.D. degree

with a thesis titled "Optimum tests of a certain class of hypotheses specifying the value of a correlation coefficient."

Erich was not the first of Neyman's Berkeley Ph.D. students, but he was the first one to be hired by the mathematics department. He held the title of assistant professor of mathematics from 1947 to 1950, and spent the first half of 1950–1951 as a visiting associate professor at Columbia, and as a lecturer at Princeton during the second half of that year. Partly to allow more time for the tumultuous situation created in Berkeley by the anti-Communist loyalty oath to settle down, and partly to make a decision on an offer from Stanford, Erich spent the year of 1951–1952 as a visiting associate professor at Stanford. Erich decided to go back to Berkeley, but not before he was able to persuade Neyman not to require him to do consulting work for the statistical laboratory. (Stanford's offer explicitly mentioned that Erich was not expected to do any applied work.) On his return to Berkeley in 1952, Erich was promoted to associate professor of mathematics, and then in 1954 was promoted to professor of mathematics. In 1955, after Evans stepped down as chair of mathematics, thus providing Neyman with his opportunity for a new department of statistics, Erich's title changed to professor of statistics. In 1988, Erich became professor emeritus and then from 1995 to 1997 he was distinguished research scientist at the Educational Testing Service (ETS). In spite of his retirement in 1988, Erich continued to be professionally active and a regular participant in the social life of the department. Despite offers from Stanford in 1951 and from the Eidgenössische Technische Hochschule (ETH) in 1959, and except for short stints at Columbia, Princeton, Stanford and ETS, Erich lived in Berkeley from his arrival on January 1st, 1941 until his death on September 12th, 2009.

2. Honors, awards, service to the profession. Erich Lehmann's towering contributions to statistics have received many well-deserved accolades. Erich was an elected fellow of the Institute of Mathematical Statistics (IMS) and of the American Statistical Association (ASA), and he was an elected member of the International Statistical Institute. Remarkably, he was the recipient of three Guggenheim Fellowships (1955, 1966 and 1980) and two Miller Institute for Basic Research Professorships (1962 and 1972). The IMS honored him as the Wald lecturer in 1964—the title of his lectures being "Topics in Nonparametric Statistics." This was followed in 1988 by the Committee of Presidents of Statistical Societies (COPSS) R. A. Fisher Memorial Lecture entitled "Model Specification: Fisher's views and some later strategies." In 1975 Erich was elected fellow of the American Academy of Arts and Sciences and in 1978 he was elected member to the National Academy of Sciences. Election as an Honorary Fellow of the Royal Statistical Society followed in 1986 and the ASA recognized him with the Wilks Memorial Award in 1996. His life-long work was recognized with two Doctorates *honoris causa*, the first from the University of Leiden in 1985, and the second from the University of Chicago in 1991. The honor from Leiden carries with it the distinction of being the first Dr. *h. c.* granted by the University of Leiden to a mathematician in

a century, the previous one having been awarded to Stieltjes in 1884. In 1997, to celebrate Erich's 80th birthday, the Berkeley statistics department instituted the Lehmann fund to provide support for students. In 2000 Erich became the first Goffried Noether Award recipient and lecturer for his influential work in Nonparametrics. His Noether lecture, entitled "Parametrics Versus Nonparametrics: Two Alternative Methodologies," formed the basis for an invited paper with discussion in the *Journal of Nonparametrics* (JNPS) in 2009 [121]. Posthumously, Erich received the best JNPS paper award for 2009. His students and colleagues honored him with a set of reminiscences in 1972 (J. Rojo, ed.), a *Festschrift for Erich L. Lehmann* organized by Bickel, Doksum and Hodges in 1982 [see also Bickel, Doksum and Hodges (1983)], and a series of *Lehmann Symposia*, organized by Rojo and Perez-Abreu in 2002, and Rojo in 2004, 2007 and 2011. Perhaps surprisingly, although he was honored with the Fisher lecture, he never received the honor of being the Neyman lecturer. It may be surmised that Erich's lack of affinity for applied work impeded his being so honored.

Erich served the profession well. Although initially reluctant to serve as chair of the statistics department at Berkeley, he did so from 1973–1976. And he did it very well. Brillinger (2010) writes:

> He had always refused previously for a variety of reasons. He did it so well that I sometimes thought that he must have thought through how a Chair should behave and put his conclusions into practice. For example, to the delight of visitors and others he was in the coffee room each day at 10 a.m. He focused on the whole department—staff, students, colleagues and visitors.

During 1960–1961, Erich was IMS President and was a leader in the internationalization of the IMS [see, e.g., Lehmann (2008B) and van Zwet (2011)]. He was a member of the Executive committee of the Miller Institute (1966–1970), and a member of the committee of visitors to the Harvard Department of Statistics (1974–1980) and Princeton (1975–1980). He served as Editor of the *Annals of Mathematical Statistics* from 1953–1955 and as Associate Editor from 1955–1968. He was invited to stay on for a second term as Editor but, after accepting, had to decline. For details see Lehmann (2008B) and van Zwet (2011).

3. Books and their translations. In his youth, Erich Leo Lehmann had a desire to become a writer. In Lehmann (2008B), he wrote, "*My passion was German literature, my dream to become a writer, perhaps another Thomas Mann or Gottfried Keller.*" Surely it was this passion that drove Erich to write his successful and influential books. The list includes:

1. **Testing Statistical Hypotheses**. Three editions (1959, 1986, 2005). The 2005 edition is joint with Joseph P. Romano. The 1959 edition was translated into Russian (1964), Polish (1968) and Japanese.
2. **Basic Concepts of Probability and Statistics**, with Joseph L. Hodges. Two editions (1964, 1970). Reprinted in 2005 as part of the SIAM series Classics

in Applied Mathematics. The book was translated into Hebrew (1972), Farsi (1994), Italian (1971) and Danish (1969).
3. **Elements of Finite Probability**, with Joseph L. Hodges. Two editions (1965, 1970).
4. **Nonparametrics: Statistical Methods Based on Ranks**, with the assistance of H. J. M. D'Abrera. Hardcover edition (1975) by Holden-Day. Paperback edition (1998) by Prentice-Hall, Inc., Simon & Schuster, and then by Springer Science in 2006. The book was translated into Japanese (1998).
5. **Theory of Point Estimation**. Two editions (1983, 1998—with George Casella). The 1983 edition was translated into Russian (1991), and the 1998 edition into Chinese (2004).
6. **Elements of Large-Sample Theory**, 1999.
7. **Reminiscences of a Statistician: The Company I Kept**, 2008.

Additionally, Erich collaborated with Judith M. Tanur on the book *Statistics*: *A Guide to the Unknown*. This book went through several editions and translations [Chinese (1980) and Spanish (1992)]. Spin-offs from this book were two other books with similar titles: *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, and on which Erich collaborated. Erich served as co-editor or special editor. The complete list of books and their translations is given in Section 9.

The book *Fisher*, *Neyman*, *and the Creation of Classical Statistics* has now been published posthumously by Springer, Lehmann (2011B). Erich was finishing the manuscript at the time of his death. Juliet Shaffer worked diligently after Erich's passing to bring the book to publication form. Fritz Scholz continues work on a revision, started before Erich's death, of the *Nonparametrics*: *Statistical Methods Based on Ranks* book. The revision incorporates the use of R and the book is expected to be completed in two years.

4. Technical work. Erich's contributions are multifaceted and too many to do justice to in the allotted space. A more extensive and careful assessment of his work is provided in Rojo (2011). Here, only a small part of his work will be briefly reviewed. Some of his ground-breaking work in nonparametric statistics is discussed in this issue by van Zwet (2011).

4.1. *Early work.* While still a graduate student at Berkeley, Erich submitted a paper that was published in 1947 [2], in which the issue of what to do when a uniformly most powerful (UMP) test does not exist is discussed. Erich proposed that, due to the many tests available to choose from, one must reduce attention to a class of tests $\mathcal{F}$ with the property that for any test ϕ not in $\mathcal{F}$, there is a test ϕ^* in $\mathcal{F}$ with a power function at least as good as that of ϕ. And if ϕ_1 and ϕ_2 are two tests in $\mathcal{F}$, then neither one dominates the other. In addition, the paper characterizes the

Erich L. Lehmann at dinner during the 2nd Lehmann Symposium—May 2004. Shown also in the picture, David Cox, Ingram Olkin, Peter Bickel, Shulamith Gross, Emmanuel Parzen and Loki Natarajan. Kjell Doksum, Joseph Romano and Gabriel Huerta are seen in the background.

Erich L. Lehmann in 1919.

Erich L. Lehmann in 1992 in El Paso, TX. Also in the picture Juliet Shaffer, Javier and Ma Luisa Rojo, and Simon Bernau.

Erich L. Lehmann in 1919, 1992 and 2004.

class $\mathcal{F}$ for a special case. Erich recognized that the class $\mathcal{F}$ may still be too large to offer much relief in finding a good solution and, therefore, other information or principles may be needed to further narrow down the class $\mathcal{F}$. Thus, the concept of minimal complete classes, that plays a fundamental role in the theory of statistical decisions of Wald (1950), was born in this paper.

In his book *Statistical Decision Functions* (1950), Wald credits Lehmann:

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

Interestingly, Neyman was not impressed by this work. In DeGroot (1986) Erich states:

> I wrote it up—it was just a few pages—and said to Neyman that I would like to publish it. He essentially said, "It's junk. Do not bother." But I sent it in to Wilks anyway.

Some of Erich's early work was motivated by the work of Hsu (1941) that dealt with optimal properties of the likelihood ratio test in the context of analysis of variance. In Lehmann (1959) [34], Erich shows that these optimal properties are consequences of the fact that the test is uniformly most powerful invariant. In addition, the paper unified optimality results of Kiefer (1958) for symmetrical nonrandomized designs, and optimality results of Wald (1942) for the analysis of variance test for the general univariate linear hypothesis. Hsu (1941) also proposed a method for finding all similar tests. Lehmann (1947) [3] extended Hsu's results to the composite null hypothesis problem, and ideas in Hsu (1941) motivated the concept of completeness in Lehmann and Scheffé (1950) [12]. Lehmann and Scheffé (1950) [12] and Lehmann and Scheffé (1955) [26] provided a comprehensive study of the concepts of similar regions and sufficient statistics. Together with Lehmann and Stein (1950) [11], where uniformly minimum variance unbiased estimators are discussed in the sequential sampling context, these papers provide the final word on certain problems in hypotheses testing and estimation.

4.2. *Minimaxity and admissibility.* Hodges and Lehmann (1950, 1951, 1952) [10, 13, 16], provided minimax estimators for several examples and the admissibility of minimax estimators and connections with Bayes estimators were discussed. In Hodges and Lehmann (1950) [10], a minimax estimator for the probability of success p in a binomial experiment is obtained by considering the Bayes estimator with respect to a beta conjugate prior that yields a Bayes estimator with constant risk. The minimax estimator thus found is admissible due to the uniqueness of the Bayes estimator. The results are extended to the case of two independent binomial distributions and a minimax estimator is obtained for the difference of the probability of successes when the sample sizes are equal. The question of whether a minimax estimator exists for the difference of the success probabilities for unequal sample sizes remains an open problem. The papers also consider the nonparametric case, and methods for deriving nonparametric minimax estimators are provided

under certain conditions. The concept of complete classes having been formalized by Wald (1950), the paper also shows that, for convex loss functions, the class of nonrandomized estimators is essentially complete. Hodges and Lehmann (1951) [13] used a different approach to obtain minimax and admissible estimators when the loss function is a weighted squared error loss. The method requires the solution of a differential inequality involving the lower bound for the Mean Squared Error. Various sequential problems were discussed and minimax estimators were derived. Hodges and Lehmann (1952) [16] proposed finding estimators whose maximum risk does not exceed the minimax risk by more than a given amount r. Under this restriction it was proposed to find the *restricted Bayes solution* with respect to some prior distribution λ. That is, find δ_0 that minimizes $\int R(\delta,\theta)\,d\lambda(\theta)$ subject to $\sup_\theta R(\delta,\theta) \le r$. Conditions were discussed for the existence of restricted Bayes estimators and several examples were provided that illustrate the method. It was argued that Wald's theory can be extended to obtain results for these restricted Bayes procedures.

Wald (1950) obtained the existence of least favorable distributions under the assumption of a compact parameter space. Lehmann (1952) [17] addressed this issue and, in the case of hypothesis testing and, more generally, in the case where only a finite number of decisions are available, Lehmann weakened the conditions for the existence of least favorable distributions. Lehmann and Stein (1953) [20] proved the admissibility of the most powerful invariant test when testing certain hypotheses in the location parameter family context.

4.3. *Hypothesis testing*. Erich's work on hypothesis testing is well known. Here some aspects of that work are briefly reviewed.

4.3.1. *Composite null hypotheses*. Lehmann (1947) [3] and Lehmann and Stein (1948) [5] studied the problem of testing a composite (null) hypothesis. The 1947 paper extends the work of Scheffé (1942). Suppose that Θ is a k-dimensional parameter space. Let Θ_0 be the subset of Θ given by $\{\bar\theta \in \Theta : \theta_i = \theta_i^0\}$, for one $i = 1,\dots,k$. Then the null hypothesis $H_0 : \bar\theta \in \Theta_0$ is an example of a composite (null) hypothesis with one constraint, and the parameters θ_j, $j \ne i$, are nuisance parameters. Neyman (1935) provided Type B regions for the case of a single nuisance parameter. These results were extended by Scheffé to the case of several nuisance parameters (under H_0), and Scheffé provided sufficient conditions for these Type B regions to also be Type B_1 (uniformly most powerful unbiased) regions. Lehmann (1947) [3] utilized Neyman and Pearson's (1933) and Hsu's (1945) methods to determine the totality of similar regions and extended Scheffé's results to obtain uniformly most powerful tests against one-sided alternatives. Hsu's method was also employed to obtain UMP regions in cases, for example, location and scale exponential and uniform distributions, where Neyman and Pearson's method does not apply. The above approach is not as fruitful in the case of more than one constraint, but results of Hsu (1945) are useful in this regard.

In Lehmann and Stein (1948) [5] the problem of testing a composite hypothesis against a single alternative is addressed by relaxing the condition of similarity to one requiring only that $\int_{\Omega^*} f(x)\,d \leq \alpha$ or all $f \in \mathcal{F}$, where Ω^* denotes the critical region of the test. Adapting the Neyman–Pearson lemma to hold in this case, sufficient conditions for the existence of most powerful tests were derived. The results for Student's problem, with composite null hypothesis given by the normal family with mean 0 and unknown variance, and the simple alternative hypothesis given by the normal distribution with known parameters were somewhat surprising; see Lehmann (2008B), page 48.

4.3.2. *Likelihood ratio tests*. Lehmann (1950, 1959, 2006) [9, 34, 118] deal with the likelihood ratio principle for testing. Although this principle is "intuitive" and provides "reasonable" tests, it is well known that it may fail. The papers examine different aspects of the problem focusing on the optimality of the likelihood ratio test in some cases, and in its total failure in other cases.

Lehmann (1959) [34] considered a class of invariant tests endowed with an order that satisfies certain properties. It was then shown that, in this case, the likelihood ratio test's optimality properties follow directly from the fact that the test is uniformly most powerful invariant. See also Section 4.1.

In Lehmann (2006) [118] and Lehmann (1950) [9], properties of tests produced by other approaches are examined and compared to the likelihood ratio tests. For example, when the testing problem remains invariant with respect to a transitive group of transformations, the *likelihood averaged or integrated with respect to an invariant measure approach* in Lehmann (2006) [118] produces tests that turn out to be uniformly at least as powerful as the corresponding likelihood ratio test, with the former being strictly better except when the two coincide; and in the absence of invariance, the proposed approach continues to improve on the likelihood ratio test for many cases. Lehmann (1950) [9] was discussed in Section 4.1.

5. Orderings of probability distributions. Lehmann's work on orderings of probability distributions was motivated in part from the need to study properties of power functions. Thus, Lehmann (1955) [27] discussed the stochastic and monotone likelihood ratio orderings. The latter plays a fundamental role in the theory of uniformly most powerful tests and both can be characterized in terms of the function $K(u) = GF^{-1}(u)$; see, for example, Lehmann and Rojo (1992) [98]. It is this function K that also plays a fundamental role in the Lehmann Alternatives and, hence, is also connected with the Cox proportional hazards model and has now spilled over to the literature on Receiving Operating Characteristic (ROC) curves. A different collection of partial orderings between distributions F and G can be defined in terms of the function $K^* = F^{-1}G(x)$. Bickel and Lehmann (1979) [64] considered the dispersive ordering defined by requiring that

$K^*(y) - K^*(x) \leq y - x$ for all $y > x$, and considered several of its characterizations. This concept is equivalent, under some conditions, to a tail-ordering introduced by Doksum (1969). This function, K^*, is also useful in comparing location experiments (Lehmann (1988) [85]).

Lehmann (1966) [47] introduced concepts of dependence for random variables (X, Y). This work has attracted a lot of attention in the literature from applied probabilists and statisticians alike.

6. Philosophical work. Erich believed in the frequentist interpretation of probability and in the Neyman–Pearson–Wald school of optimality, but recognized that both perspectives have their limitations. See, for example, page 188 of Lehmann (2008B). Bickel and Lehmann (2001) [110, 111] discussed some of the philosophical shortcomings of a frequentist interpretation of probability. Erich felt that optimality considerations achieve solutions that may lack robustness and other desirable properties. His work on foundational issues focused on the following: (i) model selection; (ii) frequentist statistical inference; (iii) Bayesian statistical inference; and (iv) exploratory data analysis.

Restricting attention to (ii), (iii) and (iv), Erich viewed the trichotomy as being ordered by the level of model assumptions made. Thus, (iv) is free of any model assumptions and allows the data to speak for itself, while the frequentist approach relies on a probability model to evaluate the procedures under consideration. The Bayesian approach, in addition, brings in the prior distribution. Erich felt that none of these approaches is perfect. Motivated by this state of affairs, Lehmann (1985, 1995) [82, 104] developed ideas that bridge the divide created by the heated philosophical debates. Lehmann (1985) [82] discussed how the Neyman–Pearson–Wald approach contributes to the exploration of underlying data structure and its relation with Bayesian inference. Lehmann (1995) [104] continued with this line of thought:

> In practice, the three approaches can often fruitfully interact, with each benefiting from considerations of the other points of view. It seems clear that model-free data analysis, frequentist and Bayesian model-based inference and decision making each has its place. The question appears not to be—as it is often phrased—which is the correct approach but in what circumstances each is most appropriate.

Erich's balanced view of foundational issues is appealing. His work reflects the belief that no single paradigm is totally satisfactory. Rather than exacerbating their differences through heated debates, he proposed that a fruitful approach is possible by consolidating the good ideas from (ii), (iii) and (iv)—with (iii) serving as a bridge that connects all three. Although his original position was solidly in the frequentist camp, he shifted, somewhat influenced by classical Bayesian ideas. However, he felt that a connection with the radical Bayesian position was more challenging. He states in Lehmann (1995) [104] that "*bridge building to the* "*radical*" [*Bayesian*] *position is more difficult*." A definition of the radical Bayesian

position is not provided, but it can be surmised that this refers to a paradigm that insists on the elicitation of a prior distribution at all costs. In Lehmann (2008B), he writes:

> However, it seems to me that the strength of these beliefs tends to be rather fuzzy, and not sufficiently well defined and stable to assign a definite numerical value to it. If, with considerable effort, such a value is elicited, it is about as trustworthy as a confession extracted through torture.

7. Ph.D. students. I first attended U.C. Berkeley during the Fall of 1978. My first course was statistics 210 A—the first quarter of theoretical statistics. The recollections of my days as a student during that first quarter, followed by two more quarters of theoretical statistics—statistics 210 B and C—all taught by Erich, are very vivid. During that first academic year, I was very impressed with Erich's lecturing style. He would present the material without unnecessarily dwelling too long on technical details, and in such a way that connections with previous material seemed virtually seamless. It was quite enjoyable to follow "the story" behind the theory. His lectures were so perfectly organized even when only using a few notes on his characteristic folded-in-the-coat's-pocket-yellow sheets! Regarding teaching, Erich wrote in Lehmann (2008B):

> While I eschewed very large courses, I loved the teaching that occurred at the other end of the spectrum. Working on a one-on-one basis with Ph.D. students was, for me, the most enjoyable and rewarding aspect of teaching. At the same time, it was an extension of my research, since these students would help me explore areas in which I was working at the time.

This love for one-on-one teaching produced a total of 43 Ph.D. students. Curiously, two of Erich's Ph.D. students obtained their degrees from Columbia rather than from Berkeley. That these students graduated from Columbia, rather than from Berkeley, resulted from a confluence of circumstances. Although Erich had received an invitation from Wald to visit Columbia during the 1949–1950 academic year, Erich had to postpone his visit to Columbia for the following year since Neyman took a sabbatical during the 1949–1950 academic year. After Wald's tragic and untimely death, two of Wald's students approached Erich with a request to become his students. These students are marked with an asterisk in the following table that presents the names and dissertation titles, by year of degree, for all 43 of Erich's Ph.D. students.

1950 **Colin Ross Blyth**
I. Contribution to the Statistical Theory of the Geiger–Muller Counter;
II. On Minimax Statistical Decision Procedures and Their Admissibility.

1953 **Fred Charles Andrews**
Asymptotic Behavior of Some Rank Tests for Analysis of Variance.
Jack Laderman*
On Statistical Decision Functions for Selecting One of k Populations.

1954 **Hendrik Salomom Konijn**
On the Power of Some Tests for Independence.

1955 **Allan Birnbaum***
Characterizations of Complete Classes of Tests of Some Multiparametric Hypotheses, with Applications to Likelihood Ratio Tests.
Balkrishna V. Sukhatme
Testing the Hypothesis that Two Populations Differ Only in Location.

1959 **V. J. Chacko**
Testing Homogeneity Against Ordered Alternatives.

1961 **Piotr Witold Mikulski**
Some Problems in the Asymptotic Theory of Testing Statistical Hypotheses.

1962 **Madan Lal Puri**
Asymptotic Efficiency of a Class of C-Sample Tests.
Krishen Lal Mehra
Rank Tests for Incomplete Block Designs. Paired-Comparison Case.
Subha Bhuchongkul Sutchritpongsa
Class of Non-Parametric Tests for Independence in Bivariate Populations.
Shishirkumar Shreedhar Jogdeo
Nonparametric Tests for Regression Models.

1963 **Peter J. Bickel**
Asymptotically Nonparametric Statistical Inference in the Multivariate Case.
Arnljot Høyland
Some Problems in Robust Point Estimation.

1964 **Milan Kumar Gupta**
An Asymptotically Nonparametric Test of Symmetry.
Madabhushi Raghavachari
The Two-Sample Scale Problem When Locations are Unknown.
Ponnapalli Venkata Ramachandramurty
On Some Nonparametric Estimates and Tests in the Behrens–Fisher Situation.
Vida Greenberg
Robust Inference in Some Experimental Designs.

1965 **Kjell Andreas Doksum**
Asymptotically Minimax Distribution-Free Procedures.
William Harvey Lawton
Concentration of Random Quotients.

1966 **Shulamith Gross**
Nonparametric Tests When Nuisance Parameters Are Present.
Bruce Hoadley
The Theory of Large Deviations with Statistical Applications.
Gouri Kanta Bhattacharyya
Multivariate Two-Sample Normal Scores Test for Shift.

James Nwoye Adichie
Nonparametric Inference in Linear Regression.
Dattaprabhakar V. Gokhale
Some Problems in Independence and Dependence.

1968 **Frank Rudolph Hampel**
Contributions to the Theory of Robust Estimation.

1969 **Wilhelmine von Turk Stefansky**
On the Rejection of Outliers by Maximum Normed Residual.
Neil H. Timm—Co-advisors Erich Leo Lehman and Leonard Marascuilo
Estimating Variance–Covariance and Correlation Matrices from Incomplete Data.
Louis Jaeckel
Robust Estimates of Location.

1971 **Friedrich Wilhelm Scholz**
Comparison of Optimal Location Estimators.
Dan Anbar
On Optimal Estimation Methods Using Stochastic Approximation Procedures.

1972 **Michael Denis Stuart**
Components of 2 for Testing Normality Against Certain Restricted Alternatives.
Claude L. Guillier
Asymptotic Relative Efficiencies of Rank Tests for Trend Alternatives.
Sherali Mavjibhai Makani
Admissibility of Linear Functions for Estimating Sums and Differences of Exponential Parameters.

1973 **Howard J. M. D'Abrera**
Rank Tests for Ordered Alternatives.

1974 **Hyun-Ju Yoo Jin**
Robust Measures of Shift.

1977 **Amy Poon Davis**
Robust Measures of Association.

1978 **Jan F. Bjornstad**
On Optimal Subset Selection Procedures.

1981 **William Paul Carmichael**
The Rate of Weak Convergence of a Vector of U-Statistics Generated by a Single Sample.
David Draper
Rank-Based Robust Analysis of Linear Models.

1982 **Wei-Yin Loh**
Tail-Orderings on Symmetric Distributions with Statistical Applications.

1983 **Marc J. Sobel**
Admissibility in Exponential Families.

1984 **Javier Rojo**
On Lehmann's General Concept of Unbiasedness and the Existence of L-unbiased Estimators.

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10. Epilogue. Erich's sensitivity toward others, contagious zest for life, gentle spirit, fundamental contributions to statistics and remarkable contributions to human resources development, have been recorded, chronicled and honored through various mechanisms. After his death, Erich's life was celebrated with a memorial service that took place at the Berkeley women's faculty club on November 9th, 2009. The service was well attended. His family, friends, students, collaborators and colleagues paid homage. Peter Bickel organized a memorial session during the 2010 Joint Statistical Meetings in Vancouver (Persi Diaconis, Juliet Shaffer and Peter Bickel speakers). The session was very well attended with standing room only. The respect and appreciation for Erich was international. Willem van Zwet organized a memorial session during the 73rd IMS annual meeting in Gothenburg, Sweden in 2010 (David Cox, Kjell Doksum, Willem van Zwet, speakers), and Peter Bickel gave a lecture during the Latin American Congress of Probability and Mathematical Statistics (CLAPEM) in Venezuela, November 2009, in remembrance of Erich Lehmann.

Recordings of various Erich talks are freely accessible to the public for viewing. These include lectures he gave during the second and third Lehmann Symposia at Rice University. Obituaries by Peter Bickel (2009) and David Brillinger (2010) provide additional information about the life and work of Erich L. Lehmann. Other sources that present fascinating accounts of Erich's work and life include Lehmann

(2008B), DeGroot (1986) and Reid (1982). A collection of selected works edited by the author will soon be published by Springer. The *Selected Works of E. L. Lehmann* provides an extended bibliography and, through invited vignettes, examines more closely the various facets of his work.

Stigler (2009), Rojo and Perez-Abreu (2004), Rojo (2006, 2009a, 2009b) and van Zwet (2011) provide additional anecdotes and commentaries.

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