

Columbia University Statistics

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Statistical Activities at Columbia Before 1946

Statistical activities at Columbia predate the formation of the department. Faculty members from other disciplines had carried out research and instruction of statistics, especially in the Faculty of Political Sciences (Anderson 1955). Harold Hotelling's arrival in 1931, a major turning point, propelled Columbia to a position of world leadership in Statistics. Hotelling's primary research activities were in Mathematical, Economics, and Statistics but his interests had increasingly shifted toward Statistics. According to Paul Samuelson (Samuelson 1960), "It was at Columbia, in the decade before World War II, that Hotelling became the Mecca towards whom the best young students of economics and mathematical statistics turned. Hotelling's increasing preoccupation with mathematical statistics was that discipline's gain but a loss to the literature of economics." His many contributions include canonical correlation, principal components and Hotelling's T^2 .

In 1938, after attending a conference of the Cowles Commission for Research in Economics, Abraham Wald, concerned by the situation in Europe, decided to stay in the United States. With Hotelling's assistance, Wald came to Columbia on

A substantial part of this chapter was developed based on Professor T. W. Anderson's speech during our department's sixtieth year anniversary reunion. We thank Professor Anderson for his help (as a founding member of our department) during the preparation of this chapter, our current department faculty members, Professors Ingram Olkin, and and Tze Leung Lai for their comments and suggestions on earlier versions of this chapter.

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a fellowship from the Carnegie Corporation (Wolfowitz 1952; Anderson 1955) and began to study Modern Statistics with Hotelling, becoming a regular faculty member in the Economics department in 1941. In addition to their prolific research in Statistics, Hotelling and Wald also carried out broad and advanced instruction and training in Statistics at Columbia, which was “ahead of that offered at any other American university.” Anderson (1955) As a result of their efforts, in 1942, a Joint Committee on Instruction was appointed to supervise the Ph.D. in Mathematical Statistics, which consisted of Frederic Mills (Economics), Paul Lazarsfeld (Sociology), Helen Walker (Teachers College), and people from the Psychology department and Columbia College. These activities in research, instruction and training in Statistics paved the road for the foundation of a new department.

On July 1st, 1942, soon after the United States entered World War II, the Statistical Research Group (SRG), financed by the Applied Mathematics Panel of the National Defense Research Committee, was formed at Columbia University to support the emerging statistical needs of the war effort (Rees 1980). Over the 39 months of its duration, a total of 18 principal statisticians (mostly visitors from other universities) served in the SRG with W. Allen Wallis as director. This was “the most extraordinary group of statisticians ever organized taking into account both number and quality” (Wallis 1980). The SRG played an important role in the history of Statistics in the United States. As also documented in the *University of Chicago* chapter, members of the SRG produced a number of important contributions to Modern Statistics, the most important of which is sequential analysis (see Wallis (1980) for his full account of the origins of sequential analysis). The SRG also prepared a number of statisticians for their future career as leaders in Statistics and other fields, as evidenced by the fact that eight members became IMS presidents, four became ASA presidents, two received the Nobel Prize in Economics, and two became university presidents.

Founding of a Statistics Department, Early Years and Influential Contributions

Instruction and research in Statistics continued at Columbia during and after the war, due to the efforts of Hotelling and Wald (Anderson 1955). In 1946, Hotelling moved to North Carolina to help found the Statistics department at UNC. He also invited Wald to join him. Afraid of losing two prominent scholars in Economics and Statistics, Columbia decided to create a Statistics department in the Faculty of Political Science. To differentiate its purpose from the widely held perception that Statistics was primarily about data collection and analysis by means of conventional methods, the new department was named Mathematical Statistics,¹ referring

¹ As more and more departments of Statistics were formed in the country, in November, 1982, Columbia decided to change its name to the simpler “Department of Statistics”.

to a scientific discipline that focused more on developing new methodology using sophisticated Mathematics.

The new department had three founding members: Wald, Jacob Wolfowitz, and Theodore W. Anderson. During the first year, Jerzy Neyman and Joseph Leo Doob were visiting professors; Wald unsuccessfully invited them to join Columbia. With Howard Levene joining the faculty in 1947, Henry Scheffé in 1948, and Kai Lai Chung in 1949 (as a research associate), the department started to take form, small yet vigorous. These were exciting years. The faculty members were productive and contributed a number of seminal papers, including:

- Wald, A. and J. Wolfowitz (1948). “Optimum Character of the Sequential Probability Ratio Test.” Annals of Mathematical Statistics **19**(3): 326–339.
- Anderson, T. W. and H. Rubin (1949). “Estimation of the Parameters of a Single Equation in a Complete System of Stochastic Equations.” Annals of Mathematical Statistics **20**(1): 46–63.
- Levene, H. (1949). “On a Matching Problem Arising in Genetics.” Annals of Mathematical Statistics **20**(1): 91–94.
- Wald, A. (1949). “Note on the Consistency of the Maximum Likelihood Estimate.” Annals of Mathematical Statistics **20**(4): 595–601.
- Anderson, T. W. (1951). “Estimating Linear Restrictions on Regression Coefficients for Multivariate Normal Distributions.” Annals of Mathematical Statistics **22**(3): 327–351.
- Anderson, T. W. and D. A. Darling (1952). “Asymptotic Theory of Certain Goodness of Fit Criteria Based on Stochastic Processes.” Annals of Mathematical Statistics **23**(2): 193–212.
- Kiefer, J. and J. Wolfowitz (1952). “Stochastic Estimation of the Maximum of a Regression Function.” Annals of Mathematical Statistics **23**(3): 462–466.
- Scheffé, H. (1952). “An Analysis of Variance for Paired Comparisons.” Journal of the American Statistical Association **47**(259): 381–400.
- Levene, H. (1953). “Genetic Equilibrium When More Than One Ecological Niche Is Available.” American Naturalist **87**(836): 331–333.
- Scheffé, H. (1953). “A Method for Judging All Contrasts in the Analysis of Variance.” Biometrika **40**(1–2): 87–104.

Because the department was small, a scheme was developed to invite faculty to teach. In addition to Neyman and Doob, the department also hosted other visitors, including R. C. Bose, Donald Darling, P. L. Hsu, Salem Khamis, Michele Loève, Erich Lehmann, E. J. G. Pitman, S. N. Roy, John Curtis, Joe Gani, William Feller, Albert Bowker, Harald Cramér, Wassily Hoeffding, Gerald Lieberman, Leo Goodman, Theodore E. Harris, Klaus Krickeberg, Sigetti Moriguti, Harold Ruben, Milton Sobel, Bernard Friedman, Warren Hirsch, W. J. Youden, Jerome Cornfield, and Somish Das Gupta. Many of them taught courses. At that time, there were few textbooks in Probability and Statistics. According to Anderson, “a number of basic books in our field of statistics in some sense came out of the teaching activities of the department”. When Doob was a visiting professor, his course on probability theory contained a lot of new material and ideas that were incorporated into his book



Fig. 1 Founding members of Statistics Department at Columbia: Hotelling, Wald, Wolfowitz, and Anderson. Even though Hotelling left before the department was officially established, we included him here as he was so instrumental for the developments at Columbia that led to the creation of the department

Stochastic Processes. Erich Lehmann was working on his book on *Testing Statistical Hypotheses*. Loève's book on Probability Theory was partially developed at Columbia. Anderson's book, *An Introduction to Multivariate Statistical Analysis*, came out of his lectures at Columbia. Henry Scheffé wrote his book, *The Analysis of Variance*, while at Columbia. Kai Lai Chung wrote one of his books largely there.

In November 1950, Wald took a trip with his wife to visit universities and research centers in India. On December 13, 1950, their flight from northern India to southern India crashed in the Nilgiris district, killing all abroad (Wolfowitz 1952). Despite his career being tragically cut short, during his years at Columbia (1939–1950), Wald published nearly 70 papers, two books, and made several important contributions to Statistics. Among them, the most widely known (besides those mentioned above) are:

- Wald, A. (1939). “Contributions to the theory of statistical estimation and testing hypotheses.” *Annals of Mathematical Statistics* **10**: 299–326.
- Wald, A. (1940). “The fitting of straight lines if both variables are subject to error.” *Annals of Mathematical Statistics* **11**: 284–300.
- Mann, H. B. and A. Wald (1943). “On the Statistical Treatment of Linear Stochastic Difference Equations.” *Econometrica* **11**(3–4): 173–220.
- Wald, A. (1943). “Tests of statistical hypotheses concerning several parameters when the number of observations is large.” *Transactions of the American Mathematical Society* **54**(1–3): 426–482.
- Wald, A. (1945). “Sequential Tests of Statistical Hypotheses.” *Annals of Mathematical Statistics* **16**(2): 117–186.
- Wald, A.: *Sequential Analysis* (1947), John Wiley and Sons.
- Wald, A.: *Statistical Decision Functions* (1950), John Wiley and Sons.

Ups and Downs

Wald's untimely death was not only a monumental loss but also a major blow to the young department, as keeping Wald at Columbia had been the primary reason for the birth of the department. For more than 40 years after Wald's death, the Statistics department remained small and survived "a series of crises," according to a conversation with T. W Anderson in *Statistical Science* (DeGroot 1986)

After Wald's death, Anderson (appointed as acting executive officer before Wald's trip), Scheffé and Levene kept the department going. The university quickly organized a committee to review the young Statistics department. In particular the committee considered the future development of the department (Columbia University Archives), including "expansion or contraction in personnel." Key questions included: (1) "should the department continue as a separate department?" and (2) after the death of Wald, should one or more appointments be made and to whom? In their March 1951 report, the committee concluded that Columbia's Statistics department remained "one of the few strong groups" but had been "severely impaired by Wald's death." It recommended Columbia keep Mathematical Statistics as a separate department and make an appointment in Theoretical Probability and Statistics to maintain international leadership in Statistics. Wolfowitz was also recommended to chair the department (referred to as executive officer at that time).

Statistics was expanding rapidly in the 1950s, probably more so than now, with many major universities setting up departments or groups. Wolfowitz was recruited away from the small Columbia department by Cornell in 1951. Fortunately, however, the department was able to successfully recruit Howard Raiffa. Aryeh Dvoretzky, who worked with Wald and Wolfowitz, also spent a fraction of his time at Columbia. Within a year, the department was reviewed a second time, resulting in the formation of a special committee for the academic year of 1952–1953, to fill several possible permanent and visiting positions (Columbia University Archives). Then, Scheffé received an offer from Berkeley in March 1953 and decided to accept it. He officially resigned on April 9, 1953. During the 1952–1953 academic year, Herbert Robbins of the University of North Carolina at Chapel Hill was at the Institute for Advanced Study and the department saw an opportunity. With efforts from Anderson, Levene, Raiffa and Herbert Solomon (then at Teachers College), Robbins accepted an offer from Columbia University, joining the department in the fall of 1953. During the critical times between November 1950 and the summer of 1953, the department held together strong due to the devotion of her very few members: Anderson, Scheffé, Levene, Raiffa, and Solomon, who supported the many daily activities (teaching, supervision, committee, planning, and recruiting) that were key to the survival of a small yet vital department.

The department stabilized after Robbins' arrival. From 1953 to the mid 1960s, the department hired a number of assistant professors: Jerome Sacks, Emanuel Parzen, Gopinath Kallianpur, Ronald Pyke, Lajos Takács, Donald Ylvisaker,

Simeon Berman, Cyrus Derman, Ronald Schauffele, Innis Abrahamson, Morris Skibinsky, Max Woodbury, Leon Gleser, David Siegmund, Alvin Baranchik, and John Rolph. The department also made special appointments to people in the New York City area. Chief among them were Colin Mallows (At & T Bell Labs) and Y. S. Chow (IBM Watson Center).

A similar crisis occurred in 1967–1968, when Robbins received multiple offers and took a 2-year leave to visit several places, and Anderson decided to join Stanford. But the return of Robbins and David Siegmund² and the hiring of Y. S. Chow resulted in another period of stability and productivity, lasting to the mid 80 s. During this period, a number of assistant professors were hired, including Burton Singer, Raoul Lepage, Tze Leung Lai, Jack Cuzick, Bruce Levin, Richard Bradley, Ioannis Karatzas, and Steven Lalley. In 1981, John Van Ryzin joined the department (jointly with the division of Biostatistics).

Another crisis developed in the late 1980s, starting with the retirements of Levene (1984) and Robbins (1985). Then came the departures of Singer (1985) to Yale and Lai (1986) to Stanford, followed by the death of Van Ryzin (1987). Karatzas played the key role in ensuring the survival of the department at this time. The department also received help and support from alumni, former members, and friends at other institutes and in the industry.

On February 27, 1992, Howard Levene made a \$1 million pledge for an endowed professorship in Statistics. It was his hope that this gift will “insure the survival of this small but vital department.” Mentioned in the public announcement, Columbia made the decision to name this professorship after Levene in appreciation of his lifelong devotion to teaching and research at Columbia. After spending 1 year visiting the department in 1991–1992, Paul Meier officially joined the department in 1992 as the new chair and became the first holder of the Howard Levene Professorship. Heyde arrived at the same time and added further strength in applied probability. Since then, the department has been stable and growing.

60 Years of Evolution: Space, Name, Undergraduate and Graduate Teaching

Due to its close relation with Economics, the Department of Mathematical Statistics was initially located within the Faculty of Political Science, occupying several offices in Fayerweather Hall, where Economics was housed. The department ran into space issues (scattered and inadequate space) in the late 60 s and was gradually moved to the Mathematics building between 1968 and 1971. Due to another wave of rapid growth after 2000, in 2004, the department, still part of the

² Siegmund was assistant professor at Columbia from 1966 to 1967 before joining Stanford in 1967.



Fig. 2 Photographic memories from the 1970s and 1980s. *Left* Robbins and Lai in the departmental office. *Right* photos of Siegmund and Robbins from the 1970s



Fig. 3 The “ever-lasting” Howard Levene

Graduate School of Arts and Sciences, moved to its current location in Columbia’s new building for the School of Social Work.

For a brief time, the department of Mathematical Statistics was also home for Computer Science at Columbia under the leadership of Jonathan L. Gross until the formation of a new Computer Science department in the Engineering school. During that time, the department’s name temporarily changed to “Mathematical



Fig. 4 Holiday party during Meier's visit in 1991 or 1992. From left to right in the two panels: de la Peña, Heyde, Kalicharan, Civtanic, Spivak, Meier, Lo, and Levene

Statistics and Computer Sciences.” The first Ph.D. in Computer Science was awarded in May, 1977.

The department was initially formed as a strictly graduate department, primarily to avoid competing with other departments for the teaching of undergraduate Statistics. However, around 1950, it began teaching elementary Statistics to students enrolled in the School of General Studies, which is for students beyond their usual college age seeking part or full time undergraduate education. Starting in the mid 1960s, undergraduate teaching became a primary function of the department. In a letter dated Oct 1966, Levene reported that the department was offering undergraduate service courses to a total of 330 students. Another report in fall 1977 stated that the department was offering introductory Statistics with and without calculus, which were attended by a total of 132 students. Although the discussion of majors can be found in earlier departmental reports, the official record at Columbia states that the major in Statistics was established in 1982. Over the years, a concentration (minor) and multiple joint majors—Economics-Statistics, Mathematics-Statistics, Political Science-Statistics—were created to accommodate different interests from the undergraduate population. As part of a nationwide trend, the undergraduate major in Statistics at Columbia has become an increasingly popular choice, with more than 100 majors/minors last year.

The graduate teaching of statistics started even before the department was formed. As mentioned earlier, around the time the SRG was launched, a special committee (the Joint Committee on Instruction) on the Ph.D. program in mathematical statistics was also formed. The committee included Frederic Mills (Economics), Paul Lazarsfeld (Sociology), Helen Walker (Teachers College) and people from the Psychology department and Columbia College. Kenneth Arrow was in the program but switched to Economics after getting his masters degree. Abe Girshick and William Madow were also in that program. By the time the

department was formed, there were many graduate students participating under the GI Bill, and some of them held jobs in New York City. To accommodate these students, courses were offered in late afternoons and evenings. As a center in the New York area, many students outside Columbia University came to audit courses offered by the department. For example, Herman Chernoff,³ and Franco Modigliani who later received the Nobel Prize in Economics, took Anderson's time series course. When Doob was teaching a course on stochastic processes, many students from NYU took it. In recent years, with the expansion of the Ph.D. and master's programs, total enrollments in graduate courses now exceeds 1000.

Contributions to Statistics

Graduates

The first Ph.D. graduate of the department was Howard Levene in 1947, who then became an "ever-lasting" member of the department. The first female Ph.D. graduate was Rosedith Sitgreaves in 1952, who worked with T. W. Anderson on the behavior of classification procedures. Sitgreaves remained in academia until her retirement in 1981 and held professorships at Stanford, Columbia Teachers College, and California State University. Among early doctoral graduates (before 1970) in Statistics from Columbia, Bowker (1949), Girshick (1947), and Stein (1947) played important roles in the formation and build-up of the Stanford University statistics department. In particular, Bowker became its founding chair in 1948, while officially still a Ph.D. student at Columbia. He later also served as Chancellor of the City University of New York (1963–1971) and Chancellor of the University of California at Berkeley (1971–1980). Other students in the first 25 years of the department's history included⁴ :

- 1946–1955: Ralph Brookner (Wald), Howard Levene (Wolfowitz), Charles Stein (Wald), Gobind Ram Seth (Wolfowitz), Edward Paulson (Wald), Abe Girshick (Wald), Albert Bowker (Hotelling), Gottfried Noether (Wolfowitz), Stanley Issacson (Scheffé), Henry Teicher (Wolfowitz), Robert E. Bechhofer (Anderson), Milton Sobel (Wald and Wolfowitz), Jack Kiefer (Wolfowitz), Louis Cote (Chung), Jack Laderman (Wald), Rosedith Sitgreaves (Anderson), Lionel Weiss (Anderson), Allan Birnbaum (Raiffa), Cyrus Derman (Robbins), Richard Savage (Levene), Zivia Wurtele (Wald and Robbins), and William Kruskal (Levene).

³ Chernoff was a student at Brown. Because Brown did not have anyone to be an adviser in statistics, Chernoff worked with Wald but was never matriculated in Columbia.

⁴ A complete list of Ph.D. in Statistics at Columbia can be found at the department's website.

- 1956–1965: Sylvain Ehrenfeld (Raiffa), M. Vernon Johns (Robbins), Leon Herbach (Raiffa), Leonard Cohen (Raiffa), Peter Frank (Derman), Judah Rosenblatt (Anderson), Ruth Zwerling Gold (Anderson), Theodore K. Matthes (Anderson), Leo J. Tick (Anderson), Simeon M. Berman (Maruyama), Peter E. Ney (Chow), Lakshmi Venkataraman (Tabács), Ester Samuel (Robbins), Theophilos Cacoulios (Anderson), Gideon E. Schwarz (Anderson), Lloyd Rosenberg (Anderson), John P. Comer (Colind), Lee R. Abramson (Anderson), Joseph L. Gastwirth (Anderson), Arthur Cohen (Anderson), Edward Pollack (Levene), Richard G. Krutchkoff (Robbins), Ora Engelberd (Takács), James Pickands, III (Berman), Jerry E. Bramblett (Robbins), Norman Starr (Robbins)
- 1966–1971: Paul Burke (Takács), David Siegmund (Robbins), Saul Shapiro (Takács), Richard B. Will (Schaufele), Paul Shaman (Anderson), Stanle L. Sclove (Baranchik), Chandan K. Mustafi (Abrahamson), Arthur J. Nadas (Siegmund), Michael Kantor (Baranchik), Joseph L. Fleiss (Anderson), Ronald S. Dick (Levene), Michael J. Wichura (Levene), Harold B. Sackrowitz (Baranchik), Pi-Erh Lin (Baranchik), George P. H. Styan (Anderson), Joseph Breuer (Levene), Stephen Strauss (Chow), Ellen S. Hertz (Teicher), Robert A. Rutledge (Levene), Richard M. Stanley (Siegmund), George P. McCabe (Robbins), Serge L. Wind (Robbins), Neville E. O'Reilly (Robbins), Neil W. Henry (Anderson), Rasul A. Khan (Robbins), Joan E. Miller (Gross), Paul Tobias (Singer), Tze Leung Lai (Siegmund), Naomi B. Robbins (Siegmund).

Contributions (Including Textbooks and Papers) by Faculty During Their Time at Columbia

The department started with a strong research program, with people pioneering in areas such as multivariate analysis, sequential analysis, statistical decision theory, and econometrics. Hotelling's seminal contributions and Anderson's book are the classics of multivariate analysis. Wald's two books laid the foundation for sequential analysis and statistical decision theory. Columbia faculty members continued the work of Wald in sequential analysis with their many important publications, including Anderson's sequential boundary, power-one tests of Robbins, and fixed-width confidence intervals of Chow and Robbins. Major advances in statistical decision theory were made by Howard Raiffa as well as by Robbins (empirical Bayes theory), Chow, Robbins and Siegmund (on sequential optimal decision) and Karatzas and Lai (on optimal stochastic control). Anderson had worked on statistical problems arising from Economics, as did Burt Singer (his paper with Heckman in *Econometrica* was cited over two thousand times).

In addition to the two books already listed under Wald's publication list, faculty members also wrote other influential books. Among them are

- Anderson, T. W. (1957). An Introduction to Multivariate Statistics.
- Chow, Y. S., Robbins, H. and Siegmund, D. (1971). Great Expectations: The Theory of Optimal Stopping. Houghton-Mifflin.
- Chow, Y. S. and Teicher, H. (1978). Probability Theory: Independence, Interchangeability, Martingales. Springer.
- de la Peña, V. and Giné, E. (1999). Decoupling: From Dependence to Independence. Springer.
- de la Peña, V., Lai, T. L. and Shao, Q. (2010). Self-Normalized Processes: Limit Theory and Statistical Applications. Springer.
- Gelman, A., Carlin, B., Stern, H. and Rubin, D. (2004). Bayesian Data Analysis. Chapman & Hall.
- Gelman, A. and Hill, J. (2007). Data Analysis Using Regression and Multilevel/Hierarchical Models. Cambridge.
- Heyde, C. C. (1997) Quasi-Likelihood and Its Application. Springer.
- Karatzas, I. and Shreve, S. E. (1988). Brownian Motion and Stochastic Calculus. Springer.
- Karatzas, I. and Shreve, S. E. (1998). Methods of Mathematical Finance. Springer.
- Jacod, J. and Protter, P. (2012). Discretization of Processes. Springer.

Current Status of the Department

The Department has grown considerably in recent years. Enrollments in undergraduate and graduate classes have grown dramatically as have demands for statistical collaborations from around the campus. The Department now has two joint faculty appointments (with Political Science and with Sociology) and expects to make more appointments of this nature in the coming years. Space has again become a critical problem for the department and we hope the University's future expansion into the Manhattanville campus will provide a long-term solution. The Department has secured a position as one of the key science departments at Columbia and looks forward to making vital contributions at the forefront of statistical research as the discipline evolves in the coming decades (Figs. [1](#), [2](#), [3](#), [4](#), [5](#)).

List of current faculty members (starting year)

- Richard Davis (2007)
- Victor de la Peña (1988)
- Regina Dolgoarshinnykh (2003)
- Yang Feng (2010)
- Andrew Gelman (1996)
- Gerardo Hernandez del-Valle (2005)
- Michael Hogan (2005)
- Martin Lindquist (2002)
- Jingchen Liu (2008)



Fig. 5 Departmental summer BBQ, May 2003. *Left* Paul and Louise Meier and Mildred Sklar. *Right* Faculty members exhibited deep interest in the open problem of how to [properly] start the grill

- Shaw-Hwa Lo (1989)
- David Madigan (2007)
- Liam Paninski (2005)
- Philip Protter (2011)
- Daniel Rabinowitz (1993)
- Bodhi Sen (2008)
- Michael Sobel (2010)
- Victoria Stodden (2010)
- Jae Kyung Woo (2011)
- Frank Wood (2009)
- Zhiliang Ying (2000)
- Hongzhong Zhang (2010)
- Tian Zheng (2002)

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- Wolfowitz, J. (1952). “Wald, Abraham 1902–1950.” Annals of Mathematical Statistics **23**(1): 1–13.