NATIONAL ACADEMY OF SCIENCES

GERTRUDE MARY COX

1900—1978

A Biographical Memoir by

RICHARD L. ANDERSON

Biographical Memoir

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Gertrude Cox

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January 13, 1900–October 17, 1978

BY RICHARD L. ANDERSON

THIS IS A FINAL TRIBUTE to a fellow statistician, fellow graduate student, employer, and—above all—best friend and well-wisher, the confidante and constant companion of my wife and children. Gertrude Mary Cox had that rare combination of administrative strength and love for her fellow man we so desperately need at the present time. A gracious, patient, tenacious visionary, she brought out the best in people. As a pioneer in the development of statistics she was a servant to science who never lost her touch with people.[1]

EARLY YEARS

Gertrude Cox was born on a farm near Dayton, Iowa, where she spent several years "roaming in the woods by the river," as she put it, "and wandering over the hills." The family then moved to the small town of Perry, Iowa, where Gertrude attended public school. A lover of competitive sports, she played on the high school basketball team. (Iowa was the center of girls' basketball in those days.)

[1] Much of what is printed here is excerpted from a 1979 obituary I prepared with Robert Monroe and Larry Nelson of North Carolina State University, "Gertrude Cox—A Modern Pioneer in Statistics," *Biometrics* 35(1979):3–7. I have also included remarks from a letter Gertrude Cox wrote to me on October 10, 1975.

The Coxes were a close-knit, midwestern family with four children—two boys and two girls. Gertrude was especially close to her mother, Emma, and later wrote of her: "I learned from my mother the value and joy of doing for other people. She nursed the sick for miles around and raised us to be active church workers."

During those early years Gertrude also learned to like making bread—perhaps because she was allowed to sell one pan of biscuits. Her excellent cinnamon rolls were famous. She always served them to us whenever we visited, and, when we left, provided one package for our son, Bill, and another for the rest of us. Gertrude loved children and always joined us on Christmas morning to see our two youngsters open their gifts.

Gertrude's early ambition was to help others. She took a two-year course in social science, then spent another two years as a housemother for sixteen small orphan boys in Montana. As preparation for becoming the superintendent of the orphanage, she decided to enroll at Iowa State College. Majoring in mathematics because it was easy for her, she elected courses in psychology, sociology, and crafts—courses useful to her in her chosen career. In 1929 she received her B.S degree.

To help pay her college expenses Gertrude did computing, George Snedecor—her calculus professor—having asked her to work with the comptometers in his computing laboratory. Speculating (forty-six years later) as to why he had chosen her for this work, she told the *Raleigh News and Observer* in May 1975, that he had probably hoped that she, the only woman in the class, would have more patience for detail work than the men.

Perhaps because of this computing experience, Gertrude became interested in statistics. But the Mathematics Department at that time would not award an assistantship to a

woman, and she financed her graduate work with assistantships in psychology and art. In 1931, she received the first Master's degree ever given by Iowa State in statistics but was turned down for a job teaching high school mathematics because she did not have the required courses in education. She decided to continue her graduate career.

Because of her love of people and her desire to learn what "made them tick," Gertrude chose psychology as her research area. With a graduate assistantship at the University of California, Berkeley, she began work on a doctorate in psychological statistics. Unfortunately for the field of psychology, she stayed only two years. In 1933, Iowa State established its Statistical Laboratory under the direction of George Snedecor, Gertrude's former mentor, and he persuaded her to return home to help him. Back in Iowa, she continued her interest in psychology and worked with several members of the Psychology Department—including its chairman (later, dean of the School of Industrial Science), Harold Gaskill—on the evaluation of aptitude tests, test scoring procedures, and the analysis of psychological data.

At the same time she was put in charge of establishing a Computing Laboratory and consulted in and taught experimental designs. In 1934 she began to teach "Design of Experiments"—a course that would become renowned—to follow Snedecor's "Statistical Methods." Most graduate students in agriculture were required to take this sequence, a requirement that was later extended to a number of other disciplines at Iowa State and was my own introduction to experimental statistics. Both the Snedecor and Cox courses were originally taught from mimeographed materials. In 1937, Snedecor's material came out in book form, but Gertrude only published her design material in 1950, when it came out as a collaborative effort with W. G. Cochran (1950,7).

Gertrude's course was built around a multitude of specific

examples (many of which I still keep in my files) in a variety of areas of experimentation. Members of her computing staff analyzed all of the data, which were then completely checked by Gertrude and the hundreds of graduate students in her course. Despite the fact that these experiments were conducted four or five decades ago, they could still furnish the basis for a solid course on the design of experiments, especially in biology and agriculture.

In her later "Advanced Experimental Design," Gertrude concentrated on her three basic principles for setting up an experiment:

(1) Experiment objectives should be set forth clearly at the outset, the experimenter having answered the following questions regarding his or her experiment: Is it a preliminary experiment to determine the course of future research or is it intended to furnish answers to immediate questions? Are the results to be put to immediate practical use or are they intended to help clarify theoretical questions? Does the researcher wish to obtain estimates or to test for significance? Over what range of experimental conditions do the results extend?

(2) The experimenter should describe the experiment in detail, clearly defining proposed treatments, size, and materials: Is a control treatment necessary for comparison with past results? Will the funds available support an experiment of sufficient size to yield useful results? Are the materials necessary for the experiment available?

(3) The experimenter should draw up an outline analyzing the data before starting the experiment.

Both as a teacher and a consultant, Gertrude particularly emphasized randomization, replication, and experimental controls as procedures essential to experimental design:

"Randomization is somewhat analogous to insurance in that it is a precaution against disturbances that may or may not occur and that may or may not be serious if they do occur. It is generally advisable to take the trouble to randomize even when it is not expected that there will be any serious bias from failure to randomize. The experimenter is thus protected against unusual events that upset his expectations. Of course in experiments

where a great number of physical operations are involved, the application of randomization to every operation becomes time-consuming, and the experimenter may use his judgment in omitting randomization where there is real knowledge that the results will not be vitiated. It should be realized, however, that failure to randomize at any stage may introduce bias unless either the variation introduced in that stage is negligible or the experiment effectively randomizes itself." (1950,7, p.8)

As she pointed out, replication not only increases the accuracy of treatment comparison, it also enables the experimenter to obtain a valid estimate of the magnitude of experimental error. She also offered the following ways to increase accuracy by improving the control of experimental techniques:

(1) Select the best experimental design for the proposed experiment;
(2) Ascertain the optimal size and shape of the experimental unit;
(3) Use uniform methods for applying treatments to experimental units;
(4) In order that every treatment operate under conditions as nearly the same as possible, exercise control over external influences;
(5) Devise unbiased methods for increasing treatment effects;
(6) Take additional measurements (covariates) often to help explain final results;
(7) Provide checks to avoid gross errors in recording and analyzing data.

Though Gertrude was enrolled in a Ph.D. program in mathematics at Iowa State, her teaching and consulting duties did not leave her enough time to write a dissertation. An "assistant" from 1933, she was appointed research assistant professor in 1939, though her design course was listed under Professor Snedecor's name.

In 1940 Snedecor was asked to recommend candidates to head the new Department of Experimental Statistics in the School of Agriculture at North Carolina State College. "Why didn't you put my name on the list?" Gertrude asked when

he showed her his all-male list of candidates, and her name was added to the accompanying letter in the following postscript: "If you would consider a woman for this position, I would recommend Gertrude Cox of my staff." This terse note was to have far-reaching consequences for statistics, for not only was Gertrude considered, she was selected. Her resignation led to a heart-rending session with Dean Gaskill, she later told me, in which he tried to convince her that she was being disloyal to her native state and to Iowa State College, and that a woman would never be accepted as a department head in a southern state.

SOUTHERN VENTURE

Gertrude Cox became the head of North Carolina State's Department of Experimental Statistics on November 1, 1940. The Board of Trustees of the Consolidated University of North Carolina authorized the establishment of the Department and confirmed Professor Cox as its head on January 22, 1941. She had strong support from the U.S. Bureau of Agricultural Economics, which had been instrumental in establishing the Department, and, in particular, from the Raleigh-based Division of Agricultural Statistics of its North Carolina Research Office.

She encouraged researchers in the School of Agriculture to attend her experimental design course and recruited capable applied statisticians to develop and teach basic statistical methods. She made these statisticians available to consult with researchers on procedures for designing experiments and analyzing data. Most faculty had been trained in one of these disciplines and acquired some statistical training as a minor area. To secure at least one faculty member for every agricultural discipline, she had to start from scratch. "There weren't any statisticians to hire when I first started," she later wrote. "I had to choose from other fields and train them."

By the time Gertrude left Ames, I had had enough of Iowa's winters and told her I would like to join her group whenever a mathematical statistician position became available. In 1942, I transferred from North Carolina State's Mathematics Department to handle statistical consulting with agricultural economists. Gertrude had decided that it was necessary to bolster the methods courses with courses in statistical theory; a graduate program was in the offing.

Another innovative feature of the Cox statistics program was a series of one-week working conferences on specific topics, such as agricultural economics and rural sociology, biological and nutritional problems, agronomic and horticultural problems, plant sciences, animal sciences, quality control, nutrition, industrial statistics, soil science, and plant breeding. Gertrude later obtained outside funds to hold two summer conferences in the mountains of North Carolina, which were attended by statisticians from throughout the United States and abroad. In addition to experimental and mathematical statistics, these conferences covered many research areas involving statistics, including life testing, operations research, clinical trials, surveys, pasture and rotation experiments, and genetics. Many were held during World War II. Gertrude, realizing the importance of quality control methods to the war effort, included engineering statisticians on the faculty.

During this period Gertrude realized still another dream. She had become a close friend of Frank Graham, the University's president, who had been instrumental in starting the statistics program in 1940. In 1944, Dr. Graham helped her get a grant from the General Education Board, founded by John D. Rockefeller, to establish and direct an Institute of Statistics to improve statistical competency in the South. This grant enabled her to add six faculty members to her department, including W. G. Cochran, who was to develop a grad-

uate program. In 1945, the General Education Board made an additional grant to establish a Consolidated University of North Carolina Institute of Statistics, with a Department of Mathematical Statistics at Chapel Hill, to concentrate on graduate training and research in statistical theory. With complementary graduate programs, the two departments produced many outstanding applied and theoretical statisticians.

Gertrude remained as head of the Experimental Statistics Department in Raleigh until 1949, when she decided to administer the Institute almost full-time, with the exception of teaching her course in experimental design. In the School of Public Health at Chapel Hill, she helped establish the Biostatistics Department, the Social Science Statistical Laboratory in the Institute for Research in Social Science, and the Psychometric Laboratory in the Department of Psychology. These two laboratories were a culmination of Gertrude's lifelong interest in the use of statistics to study human relationships.

During this time, North Carolina State statisticians began visiting a number of experimental stations to assist research programs in the use of statistical methods. Cox's Institute coordinated a number of short courses for researchers in industry and the physical sciences. One of her most important accomplishments was her successful effort, along with Boyd Harshbarger of Virginia Polytechnic Institute, to establish the Southern Regional Education Board's Committee on Statistics to develop cooperative programs for statistics teaching, research, and consulting in the South.

This Committee contributed tremendously to sound statistical programs throughout the South and fostered the spirit of cooperation that Gertrude envisaged. From 1954 to 1973 it sponsored a continuing series of six-week summer sessions and is now conducting an annual one-week Summer

Research Conference modeled on the original Gordon conferences.[2]

Gertrude's first contact with statistics came in the computing laboratory, and she remained a strong advocate of the integral connection between statistical analysis and an up-to-date computing facility. At Iowa State she had developed an excellent computing laboratory. Early in 1941 she persuaded Robert Monroe, one of her chief associates there, to come to Raleigh to develop a similar facility. I remember those old Hollerith machines at Ames and Raleigh—and the tremendous leap forward when IBM entered the electronic age. Gertrude Cox, naturally, had one of the first IBM 650s on a college campus, and North Carolina State subsequently designed for the 650 the best statistical software. From then on, Gertrude made certain that the Institute was in the forefront when it came to statistical software, and Raleigh statisticians designed the initial SAS programs.

No account of Gertrude Cox's meteoric success at the University of North Carolina would be complete without mentioning her unique ability to secure outside financial support. Though her Institute was originally funded by General Education Board grants, Gertrude Cox persuaded the Rockefeller Foundation to support a substantial program in statistical genetics. She obtained funds from the Ford Foundation for a joint program in dynamic economics with the London School of Economics. Finally, in 1952, she obtained a large grant from the General Education Board (matched by 1958) for a revolving research fund enabling the Institute to finance fundamental, nonsponsored statistical research for many years thereafter.

[2] The Committee Cox and Harshbarger founded was still operating as of 1990 under the name of the Southern Regional Committee on Statistics. Though no longer affiliated with the Southern Regional Education Board, it continues to sponsor summer research conferences.

Starting in 1958, Gertrude and seven other members of the North Carolina State statistics faculty worked out procedures for establishing a Statistical Division in the proposed not-for-profit Research Triangle Institute (RTI) between Raleigh and Chapel Hill. RTI was established in 1959, and Gertrude retired from North Carolina State in 1960 to direct its Statistics Research Division, whose major component was the sample survey unit. Retiring from that post in 1965, she continued on as a consultant for many years, even occasionally teaching her design course at North Carolina State. During her five-year tenure, RTI—and especially the Statistics Division—became an internationally recognized consulting and research organization.

Gertrude Cox was a consultant to the Pineapple Research Institute of Hawaii, the World Health Organization in Guatemala, the U. S. Public Health Service, the government of Thailand, the Pan American Health Organization, and many other organizations overseas. She served on a number of government committees including the U. S. Bureau of the Budget's Advisory Committee on Statistical Policy (1956–1958); the National Institutes of Health's Agricultural Marketing Service, Epidemiology, and Biometry Committees (1959–1964); and the National Science Foundation's Office of Education (1963–1964) and Teacher Education Section (1966). Even after retirement she served on advisory committees to the Secretary of Health, Education and Welfare (1970–1973), the Bureau of the Census, and the Department of Agriculture (1974).

PROFESSIONAL ACTIVITIES AND HONORS

Gertrude Cox's major contribution to science was her ability to organize and administer programs, but her early accomplishments in psychological statistics and experimental design were widely recognized.

Gertrude was a founding member of the International Biometric Society in 1947, served as editor of its journal, *Biometrics*, from 1947 to 1955, and was a member of its Council three times and president from 1968 to 1969. She was proud that she had attended every international meeting of the society, and, in 1964, was awarded an honorary life membership. She was also active in the International Statistical Institute and was a member of its Council in 1949, treasurer from 1955 to 1961, and chairman of the Education Committee from 1962 to 1968. She was president of the American Statistical Association (ASA) in 1956.

She was a fellow of the American Public Health Association, the American Association for the Advancement of Science, the Institute of Mathematical Statistics, and the ASA. She was also a member of the Psychometric Society, the Royal Statistical Society, and the Inter-American Statistical Institute. In recognition of her international reputation she was named honorary vice-president of the South African Statistical Association, honorary member of the Société Adolphe Quetelet of Belgium, and the Thai Statistical Association, and an honorary fellow of the Royal Statistical Society. She was a member of the honor societies Delta Kappa Gamma (education), Gamma Sigma Delta (agriculture), Pi Mu Epsilon (mathematics), Phi Kappa Phi (scholastic), and Sigma Xi (science).

In 1958, Gertrude Cox's alma mater, Iowa State University, conferred upon her an honorary Doctorate of Science as a "stimulating leader in experimental statistics . . . outstanding teacher, researcher, leader and administrator . . . Her influence is worldwide, contributing to the development of national and international organizations, publications, and councils of her field." In 1959 she received the highest recognition the Consolidated University of North Carolina can confer upon its faculty—the O. Max Gardner Award. The

citation named her a "statistical frontierswoman"—a phrase suggested by the title of her ASA presidential address, "Statistical Frontiers."

In 1970, North Carolina State University honored her once again by designating the building in which the Statistics Department is located Cox Hall, and in 1977 a Gertrude M. Cox Fellowship Fund was established for outstanding graduate students in statistics. Her most treasured honor came in 1975, when she was elected to the National Academy of Sciences.

TRAVELS

Gertrude Cox was a world traveller who particularly enjoyed working in developing countries where she could offer advice and inspiration. All of Gertrude's trips were carefully planned, usually with reservations at excellent hotels. Fascinated by Egypt, she helped establish a statistical program at Cairo University and, during the months she spent there, toured many historical sites. She was especially excited by her visits to the Sinai and to Abu Simbel.

Thailand was another of her particular favorites, and I was touched, when I visited Bangkok in 1982, by how much the Thais loved her. She loved wearing dresses she had had made from colorful Thai silk, and—a grower of orchids since her visits to Hawaii in the late 1940s—she struck up a close friendship with Rapee Sagarik, Thailand's principal orchid expert. (She grew these beautiful orchids for pleasure, not profit, and enjoyed giving them to her friends, as my own family can attest.)

CLOSING REMARKS

Gertrude Cox loved people, especially children. She always brought back gifts from her travels and was especially generous at Christmas time. She considered the faculty mem-

bers and their families to be her family and entertained them frequently. She was an excellent cook and had two hobbies that she indulged during her travels: collecting dolls and silver spoons. She learned chip carving and block printing at an early age and spent many hours training others in these arts. She loved gardening, and, when she had had a particularly hard day with administrators, would work off her exasperation in the garden. She had a fine appreciation for balance, design, and symmetry.

In 1976, Gertrude learned that she had leukemia but remained sure that she would conquer it up to the end. She even continued construction of a new house, unfortunately not completed until a week after her death. While under treatment at Duke University Hospital she kept detailed records of her progress, and her doctor often referred to them. With characteristic testy humor she called herself "the experimental unit," and died as she had lived, fighting to the end. To those of us who were fortunate to be with her through so many years, Raleigh will never be the same.

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