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A Conversation with Walter T. Federer

A. S. Hedayat

Abstract. Walter Theodore Federer was born on August 23, 1915 in Cheyenne, Wyoming. He received a B.S. in agronomy from Colorado State University in 1939. In 1941 he received the M.S. degree in plant breeding from Kansas State University. His Ph.D. in mathematical statistics from Iowa State University was awarded in 1948. He held the position of Associate Geneticist while working on the Guayule Research Project, USDA, in Salinas, California. While completing his Ph.D. at Iowa State University, he was Associate Statistician in the Agricultural Marketing Service in Ames, Iowa. His next position was as Professor of Biological Statistics in the College of Agricultural and Life Sciences at Cornell University. He was also the Administrator of the Biometrics Unit in the Department of Plant Breeding. He was awarded the Liberty Hyde Bailey Professor of Statistics Chair in 1978, which he held until retirement in 1986, since which he has had emeritus status.

Dr. Federer was Secretary and Program Coordinator for the Eastern North American Region (ENAR) of the International Biometric Society from 1950 to 1953, President-Elect of ENAR in 1959 and President in 1960. He was Chairman and Executive Secretary of the Committee of Presidents of Statistical Societies (1965–1972), Book Reviews Editor (1964–1972) and Associate Editor for *Biometrics* (1972–1976), Associate Editor for *Communications in Statistics* (1972–1994) and Associate Editor for the *Journal of Statistical Planning and Inference* (1976–1990). He was a member of national, international, university and government panels and boards, and was a consultant for several international research stations.

Dr. Federer is a Fellow of the American Statistical Association (1958), American Association for the Advancement of Science (1962), Royal Statistical Society (1964) and the Institute of Mathematical Statistics (1967), and was elected a Member of the International Statistical Institute (1974). He was awarded the Honor Alumnus Achievement Award (1972) and Honored Alumnus Award (2001) by Colorado State University, and the Distinguished Service in Agriculture Award (1988) by Kansas State University.

This conversation took place in April 2002 at University of Illinois at Chicago when Federer was invited to the Department of Mathematics, Statistics and Computer Science to present a lecture entitled "Fractional Combinatorials." This interview was partially conducted via e-mail.

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PERSONAL

Hedayat: Do you want to share with us any aspects of your family life?

Federer: I had the most wonderful parents in the world. They fashioned my principles and way of life. My father homesteaded north of Cheyenne, Wyoming. We moved to another small ranch when I was four years old. My mother immigrated from Czechoslovakia when she was eight years old. We were poor but came through the Great Depression in fine style. There was only one thing I could fault my parents on and that was that they did not teach any of their

FIG. 1. *Walt Federer in 2002.*

12 children to speak a foreign language. Mother could converse in at least seven languages. Father was fluent in German and could converse in the Scandinavian languages as he grew up in a German community in Central Illinois. Forty-four languages were spoken in homes in Cheyenne and of course many people had definite accents. Our parents did not want us to have an accent. I certainly could have used the German in college as Iowa State University required reading proficiency in German and French for the Ph.D.! Growing up in a large and congenial family was a very rewarding experience.

I was married to Lillian Elizabeth Vasey in 1945. She was a top-rated teacher of second grade in the Ames, Iowa, school system. We came to Ithaca in August 1948, adopted a son Arthur John in 1954 and built a house in 1956. Lillian and I had a great marriage until her death in February 1978 from arteriosclerosis of the heart. We drove to Iowa and Wyoming about 20 times and to the West Coast and Canada several times. We spent one sabbatical year, 1954–1955, in Hawaii with the Hawaiian Sugar Planters Association and the Pineapple Research Institute. Our 1962–1963 and 1969–1970 sabbatical years were spent in Madison, Wisconsin, with the Mathematical Research Center at the University of Wisconsin. The 1977–1978 sabbatical was spent in Sydney, Australia, at the University of Sydney. My son and I visited several countries in Europe and traveled to India, Nepal and Sri Lanka. I also visited the International Rice Research Institute in the Philippines. These years away from Ithaca were very much enjoyed by the family.

I first met my second wife, Edna Hammond Morusty, in September 1979. Guess where: square dancing. We were married in March 1982. This has been a truly wonderful marriage in that I have a talented and lovely wife, a great travel companion, and obtained three lovely, talented and beautiful stepdaughters. We traveled to many countries: Brazil, Argentina and Peru in 1980, Italy, France and England in 1982, Venezuela in 1983, and Australia in 1984 (Sydney) and 1988 (Brisbane). We toured Egypt, Kenya and South Africa in 1989, Austria and Germany in 1990, and San Francisco, San Diego and Tijuana, Mexico in 1993 with our second daughter, Suzanne. We traveled to Spain with our oldest daughter, Sandra, in 1992, visiting several museums, the World Trade Exposition and several cities. Daughters Lynn, the youngest, and Suzanne went with us to Sydney and Brisbane, Australia and Beijing, China, in 1995. In 1996, Edna and I went to the Netherlands where we met our granddaughter Robyn, a Rotary exchange student, in Amsterdam. From there we went to Paris before returning to the U.S. In 1997, we traveled to the International Maize and Wheat Improvement Center (CIMMYT) in Mexico with daughter Suzanne. In 1998, I worked with Kaye E. Basford at the University of Queensland in Brisbane. Two overseas trips were made in 1999 with Edna and daughter Suzanne: one to the International Center for Agricultural Research in the Dry Land Areas (ICARDA), Aleppo, Syria, and one to Helsinki, Finland, for the ISI Meetings with side trips to St. Petersburg, Russia, Tallinn, Estonia and Stockholm, Sweden. In 2000, we with Suzanne made another trip to CIMMYT in Mexico and to Colima University in Colima on the Pacific Ocean side of Mexico. All of the trips were in connection with meetings, joint work and/or lecturing, so they were mostly work trips for me, but my family was able to travel "around the world" with me. Edna and I do enjoy our church and plays, especially musicals. Edna takes two ballet classes and one tap-dancing class and teaches these classes when the instructor is not present. We do enjoy our 12 grandchildren and 14 great-grandchildren. Most live relatively close to us in New York and so we do a bit of grandparenting. A wonderful family and home environment can't do anything but be helpful to one's professional life. We are strongly rooted in the Christian

faith and this is a tremendous asset to a healthy, happy and successful professional life.

BECOMING A STATISTICIAN

Hedayat: How did you become interested in statistics?

Federer: Prior to entering college, I worked at the Cheyenne Horticultural Research Station in Cheyenne, Wyoming. The idea of planning and design of experiments and summarizing the results became implanted in my mind without knowing anything about statistics, the subject. Dr. LeRoy Powers, geneticist and plant breeder, had considerable influence on me in this area. I was in the college preparatory division in high school and hence took all the mathematics courses. Upon enrolling at Colorado State College (later University) in the fall of 1935, I entered as a major in forestry, changed to unclassified and then to botany for my sophomore year. Also, I enrolled in several mathematics courses. In my junior year, my major was changed to agronomy and I was under the guidance of Professor Warren E. Leonard who taught a plot technique course that included experimental design and analysis. In my senior year, I had a mathematical statistics course under Professor Andrew G. Clark using a book by Kinney. Acting upon the advice of Professor Leonard, I went to Kansas State University (KSU) to do a Masters degree in plant breeding. From my two statistics courses at Colorado State University (CSU), it appeared that I was one of the most knowledgeable individuals in statistics at KSU and consequently did a lot of statistical consulting. Upon completing my M.S. degree, Arnold J. King offered me an assistantship in the statistical laboratory of Iowa State University (ISU) even though my major was in plant breeding. During my first quarter at ISU, I contacted William G. Cochran and requested a change in my major from plant breeding to statistics. He was agreeable but told me the change would most likely delay my receiving the Ph.D. by a couple of years. That was okay with me and I entered the statistical degree program at ISU in the fall of 1941. Pearl Harbor intervened and in May 1942, I went to work with Dr. LeRoy Powers on the Guayule Research Project, located in Salinas, California. The United States was seriously short of rubber owing to the war with Japan. This project had priority over the military. My statistical knowledge obtained at CSU and my year at ISU was put to the test here as I was known as the statistician on the project. I helped design experiments, sampling procedures in laboratories and quality control procedures in a rubber factory. Dr. Powers gave me freedom to design my own experiments on guayule, even a cubic lattice experiment design with 729 entries. All of these experiences increased my interest in statistics, especially the design and analysis aspects.

DAYS AT IOWA STATE UNIVERSITY

Hedayat: When did you arrive at Iowa State and who are some of the professors with whom you had contact?

Federer: During my stay at ISU in 1941–1942 and 1944–1948, I had the great fortune of taking courses from, associating with and/or working with such individuals as Arnold J. King, George W. Snedecor, William G. Cochran, Gertrude M. Cox, Alexander M. Mood, George Brown, Oscar Kempthorne, Raymond J. Jensen, Earl E. Houseman, Morris Hansen, William Herwitz, Paul Homeyer, Theodore A. Bancroft, W. J. Youden, Daniel DeLury, Gerhardt Tintner, Mary Clem, George F. Sprague, Jay Lush, Dean Lindstrom and Ivar Johnson. This group of statisticians and biologists contributed immensely to my statistical education. I wrote papers with several of these individuals, some of which were published. T. A. Bancroft and I wrote a lengthy unpublished monograph on applications of chi-squared. A. M. Mood and I wrote an unpublished paper on indices of diversity. Many of the statistical results in survey and sampling theory and methodology well known to members of the Iowa State Statistical Laboratory in the forties appeared in publications in the fifties by individuals not connected with ISU. Much of this knowledge was taken as folklore at Iowa State.

I have many pleasant memories of associations with graduate students at Iowa State. Some of my contemporaries were Lee Crump, Clifford Maloney, Joe Dodson, George Darroch, Donovan Thompson, Daniel Horvitz, Garnet Macreary, Virgil Anderson, Juliette Perotti, Helen Bozivich, Richard E. Atkins, C. R. Weber, Kenneth Keller and others. These individuals helped to make classes, seminars and research topics more interesting and educational.

Hedayat: Do you remember your Ph.D. qualifying and defense examinations and would you share some of your experiences?

Federer: The thing I remember most about my qualifying examination is that I really messed up my explanation of likelihood ratio procedures. Professor Alexander Mood, chairman of my graduate committee, was forgiving and passed me anyway. For the next

three weeks I sat down to prove that I did know something about likelihood ratio tests, and the effort resulted in my 12th paper published in 1951 (Federer, 1951).

The defense for my Ph.D. dissertation was mired in departmental politics. Professor Oscar Kempthorne wanted me to select him as the chairman of my committee. I wrote two papers (Kempthorne and Federer, 1948a, b) with him as a peace offering. Also, he was critical of several major and minor students' theses. Professor Paul Homeyer and I helped a number of statistics minors through their difficulty. Professor George Snedecor, who was a member of my committee, sent Professor Kempthorne in his place for the oral defense of my Ph.D. dissertation. This was quite an experience. My thesis topic was selected and the research started when Professor W. G. Cochran was chairman of my committee. Professor Mood took over as chairman when Professor Cochran moved to North Carolina State University.

Hedayat: When did you meet Professor Ronald A. Fisher in person and what were your statistical conversations?

Federer: While visiting at ISU in the summer of 1952, I had the opportunity to meet with Professor Ronald A. Fisher. Professor Theodore A. Bancroft, Head of the Stat Lab, arranged to have the graduate students meet with the Great Man. During the meeting, I asked Professor Fisher, "If you were a young statistician who had just received a Ph.D., what line of statistical research would you pursue today?" He stroked his beard and after a few minutes said, "Ah yes, if I were just starting my research career, I would work on sequential experimentation. That Abraham Wald did an ingenious thing with his work on sequential sampling." I find his statement interesting because he could make the same remark today, as little has been done in this area. We don't know enough to write a Snedecor and Cochran book based on sequential experimentation and methods. I have heard several interesting stories about Professor Fisher, but perhaps this is not the place to recount them.

STATISTICS AT CORNELL

Hedayat: How did you land at Cornell University?

Federer: Dr. Harry H. Love (Head of the Department of Plant Breeding, Cornell University) came to ISU to interview individuals for a position as a statistician. I was invited to visit Cornell University in February 1948. My wife, Lillian, and I took the train from Ames, Iowa, to Ithaca, New York, arriving on the Black Diamond train from Buffalo. Cayuga Lake was frozen over for a long distance and the temperature was subzero. Dr. Love considered the wife to be an important part of hiring an individual as they needed to fit in with the individuals in the department. After a week of interviews, Dr. Love offered me an associate professor position at $5,800 per year. Since I wasn't certain that I wanted to come to Cornell, I didn't accept right away and then Dr. Love raised the ante to a professorship at $6,300. I still didn't give him my answer as my wife Lillian wasn't certain she wanted to leave her Iowa home. As is obvious, we did accept the offer and came to Cornell in August 1948.

Hedayat: How come you never left Cornell University?

Federer: The main reason I never left is Cornell University's policy of "Freedom with Responsibility." This fits my nature very well. Dr. Love was unique in hiring members of his department; he hired leaders and not assistants to a leader. He didn't believe in "Der Herr Professor" mentality. He was very successful at hiring leaders as exhibited by the positions filled by the group he hired, for example, university president, deans of the faculty, directors of organizations, et cetera. At Cornell University, a person could do just about any kind of research desired, but one CANNOT make anyone else join them in an effort. Cooperation can be sought, but can't be forced. This policy allowed me to develop my statistical research in whatever direction I liked. Of course, the grants obtained do determine the direction, but grant areas that conform to one's goals may be selected. When confronted with the opportunity to go elsewhere, I sat down and made a list of the positives and negatives of Cornell versus another place. Cornell always won. The sabbaticals (Hawaiian Sugar Planters Association and Pineapple Research Institute in Hawaii, 1954–1955; Mathematical Research Center, University of Wisconsin, 1962–1963 and 1969–1970; Sydney University, 1977 and 1984) and visits to other universities in summers let me have the opportunity to compare other places with Cornell. Cornell is, and has been, a great place to pursue my goals.

Hedayat: Cornell University is a combination of a private university and a land-grant college. Has this been a beneficial arrangement for statistics at Cornell?

Federer: Cornell has research endeavors in many fields, many of which require statistical applications and statistical research for new procedures for planning experiments and analyzing data from research activities. This has led to the various Schools and Colleges

of Cornell hiring statisticians in subject matter departments. This wide dispersion of statisticians at Cornell has resulted in there being many more statisticians at Cornell than there would have been in a single statistics department. The Departments of Animal Science and Economics have several statisticians on their payroll. Several other departments have hired statisticians. Thus the private and land grant arrangement has been beneficial for statistics.

Hedayat: When was a statistics department founded at Cornell? Why did it take so long to do this?

Federer: The Statistics Center at Cornell was established in the late forties. The Department of Mathematics has appointed a number of statisticians and probabilists from the thirties up to the present, as for example, John Curtis, Marc Kac, Will Feller, Jacob (Jack) Wolfowitz, Jack Kiefer, Roger Farrell, Larry Brown, Eugene Dynkin, Gene Hwang and Richard Durrett, among others. A number of statisticians (Pete Morton and Philip McCarthy, for example) held positions in the School of Industrial and Labor Relations beginning in the mid-forties. The Biometrics Unit was formed in 1948. It functioned as a department from 1952 onward. The name of the Plant Breeding Department was changed to the Department of Plant Breeding and Biometry in 1966. Statisticians were appointed in the Operations Research Department beginning in the early fifties (e.g., Robert Bechoffer and Lionel Weiss). Professor G. W. Salisbury was in the department of Animal Breeding in the forties and Professor Charles R. Henderson was hired in 1948. Over the years, Cornell statisticians talked about a single department beginning in the forties, but it was all talk as individuals did not want to give up what they presently had and the various school and college deans did not want to let go of any positions. A Department of Statistical Science came into being in 1997 and a Department of Biometrics (now Biological Statistics and Computational Biology) was formed in 1998.

Hedayat: Is Cornell as strong in statistics as it was in the sixties?

Federer: The research interests of Cornell statisticians today are different from the sixties. Definitely, statistical design and sampling were much, much stronger in the sixties than they are today. The J. Kiefer, D. Robson and P. McCarthy research interests in optimal design, in sampling biological populations and survey design appear to have disappeared or at least greatly diminished. I believe probability is as strong as ever. Biomathematics, modeling, statistical genetics and other areas are very strong. We may be as strong, or nearly so, in the mathematical aspects of statistics today as we were in the sixties. It is difficult to make this comparison. It is like comparing apples with oranges.

Hedayat: When I was a graduate student in statistics at Cornell in the late sixties, my statistics professors included Jacob Wolfowitz, Jack Kiefer, Larry Brown, Roger Farrell, Harry Kesten, Robert Bechoffer, Lionel Weiss, Philip McCarthy, Shayle Searle, Douglas Robson, yourself and others. Who are the counterparts of these individuals?

Federer: Many of these individuals cannot be replaced as they are one of a kind. For the most part, they have no counterparts. As I said in the previous statement, comparisons of then and now are difficult. The direction and flavor of statistics is different today than it was in the sixties.

Hedayat: You were head of the Biometrics Unit for 33 years. What role does a competent staff play in the success of a department?

Federer: During the late forties, fifties, sixties and the seventies, the stenographers in the Biometrics Unit were known as among the best or the best statistical and mathematical typists on the Cornell campus. There were no such things as personal computers and word processing packages in the forties and fifties. A stenographer was necessary to carry on the teaching and research activities of a department. The faculty relied heavily on a proficient secretarial staff. During the early period, I hired wives of Cornell students. These were extremely bright and competent individuals quick to acquire proficiency in mathematical typing. Such individuals as Annabelle Pedersen, Helen Resnick and Nola Weed were outstanding. Later on career stenographers were hired. Donna VanOrder, Helen Seamon, Norma Phalen and Pam Archin were among those worthy of mention. These were very capable individuals who helped the faculty to pursue their research, teaching and consulting activities in an efficient manner. Having a competent staff is essential to the success of any department. Currently, I personally use word processing packages such as Word, EXP and Acrobat to type my technical reports and papers for publication. Most individuals do this today and the staff of a department needs to reflect this change.

PAST RESEARCH ACTIVITIES

Hedayat: If you had to select five of your publications, what would they be and why?

Federer: For me this is a difficult question as there are nine books and somewhere in the neighborhood of

300 published papers from which to select. The ones I select now may be different tomorrow, but here is my selection. The first is my Ph.D. thesis (Federer, 1948), which was a new and innovative method for combining the results from a series of experiments with different experimental designs and different treatments. My second selection is my first book (Federer, 1955) on experimental design. This book was written from a statistical consultant's viewpoint and contained many unusual and different designs and analyses. It has been used worldwide and was reprinted by the Indian government for many years. My third selection is my paper on augmented designs (Federer, 1956). This class of experimental designs was created to replace the systematic check method in common use by plant breeders. It is currently in use worldwide and is especially popular outside the United States. This class of experimental designs is useful for screening experiments where the material to be screened is in short supply or the experimenter wishes to limit resources when screening material. I find considerable satisfaction when something I have created is so widely used in practice. My fourth selection is a book coauthored with B. L. Raktoe and A. Hedayat (Raktoe, Hedayat and Federer, 1981). This publication was selected because I feel it is a scholarly and well written work. It is currently out of print. My fifth selection is my 1999 book (Federer, 1999). This book together with Volume I (Federer, 1993) represents a new and unique approach for designing and analyzing experiments with mixtures of crops. Most publications on intercropping, the growing of more than one crop on the same area of land either simultaneously or sequentially, elicit only a fraction of the information present in an experiment. These books demonstrate statistical methods for extracting information from a data set on mixtures. As far as I know there are no other books in this area. The statistical methods presented have applications in a variety of other fields as explained in Chapter 19 of Volume II.

It is possible that a couple of projects I am currently researching will have significant impact on the statistical profession. My papers on fractional replication of factorials and on incomplete block designs are also candidates for selection. The question asks for individual works, but my contribution to a topic is usually in a series of papers, for example, seven papers on prime-power lattice designs.

Hedayat: What was the impact of your experimental design book in comparison with other books at the same time (Cochran and Cox, 1957; Kempthorne, 1952)? What was the impact of your other books?

Federer: This is a tough question as I find comparisons hard to make. My 1955 book is more theoretical than Cochran and Cox (1957) and less than Kempthorne (1952). It is written more from a statistical consulting point of view than their books. Cochran and Cox (1957) presents many tables of plans, whereas I show how to construct plans and the rationale for using them. Several thousand copies of my book have

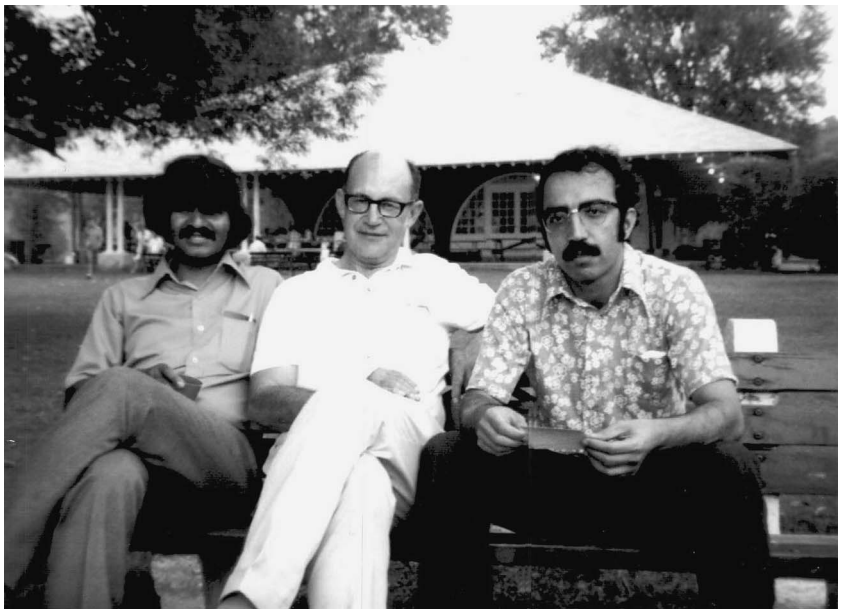

FIG. 2. *B. Leo Raktoe, Walt Federer and Sam Hedayat at Cornell University, Ithaca, in 1972.*

been sold and requests for copies are still being received. Also, permission has been received to translate the book into an Arabic language. I do not know if this has been done. The Indian government subsidized reprinting the book for many years. To some extent, discussion of complexities of split-plot and split-block designed experiments are covered in my book, but not in the other two. Papers on this topic have been written (Federer, 1975, 1977; Federer and Meredith, 1992). Most statisticians even if they know what split-plot and split-block designed experiments are, do not realize that these designs are not unique to agriculture, but can occur in many fields of investigation. My 1991 book (Federer, 1991) is a text for a concept versus a methods type of course. The statistical profession doesn't appear to be ready for a book of this type as most are not concerned with how data are collected, but only with what to do with a set of numbers that are considered to be data, for example, statistical methods texts. Techniques in Chapter 6 could save vast amounts of money in the analytical laboratories of the world. I think it is an excellent book, but that doesn't make it widely accepted.

My two recent books (Federer, 1993, 1999) have the distinction of having no competitors in the investigation of mixtures of crops. Their impact is unknown at this time. The statistical methods developed in the books could easily be translated to any other field of inquiry where mixtures of items are being investigated. Mixtures of items occur in many fields of investigation such as medicine, manufacturing, marketing, recreation, nutrition, and exercise.

Hedayat: What do you see as your most important contributions to statistics?

Federer: Additional contributions to statistics not covered above are presented here. Of course, the development of the Biometrics Unit with one faculty member (me) into a department should be mentioned. I was Professor-in-Charge and Director of the Biometrics Unit for 33 years. Whenever I tried to have D. S. Robson or S. R. Searle become the administrator, they threatened to leave. I am proud of my ability to help and motivate individuals in statistical research. This was done by obtaining research grants and bringing creative and innovative individuals to work on the grants for various lengths of time. These individuals were very productive under the climate provided. For example, in the five-year period preceding 1974, 102 papers were published with support from an NIH (National Institutes of Health) grant: of these papers, 18 were in *The Annals of Statistics*, 12 in *Biometrics* and 29 in other statistical journals. Such individuals as D. S. Robson, K. S. Banerjee, B. L. Raktoe, A. Hedayat, Ying Wang, D. Raghavarao, E. Seiden, D. A. Anderson, E. T. Parker and others were instrumental in producing this record production of pub-

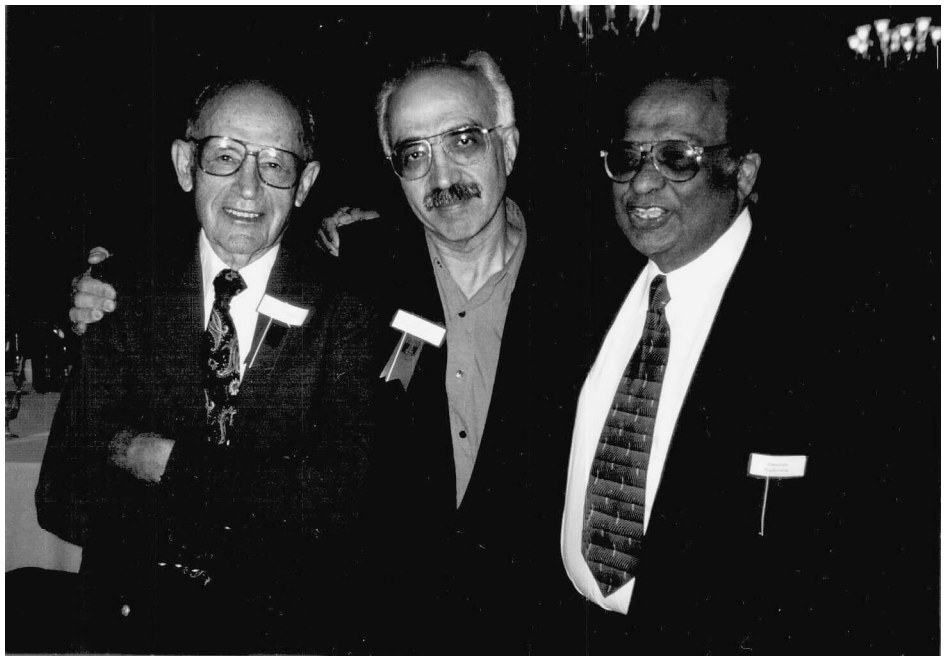

FIG. 3. *Walt Federer, Sam Hedayat and D. Raghavarao in Philadelphia attending the 60th birthday conference in honor of Damaraju Raghavarao in 1999.*

FIG. 4. *C. R. Rao, Walt Federer, Sam Hedayat and Ed Lakatos attending the 60th birthday conference in honor of Damaraju Raghavarao in Philadelphia in 1999.*

lished research papers over the years. It was always my desire to keep the research efforts of the Biometrics Unit at a very high level. My advice to colleagues and young appointees was to keep their research production at a high level, as this is what gets them promotions and offers for jobs. Administrators count the number of publications when considering promotions. I do have many ideas for research, but usually need someone with more mathematical competence to help me to solve the associated problems. The above named individuals and others have been very cooperative and helpful in this respect.

The Biometrics and Statistics Minor program of the Biometrics Unit has been very successful over the years. A large number of the minor students under D. S. Robson and myself accepted positions as statisticians and many were instrumental in pursuing research careers which involved statistical applications and theory, for example, S. R. Searle, R. C. Elston, D. A. Harville, R. S. Dunbar, M. Grosslein, R. L. Hurst, G. V. O'Bleness, H. Regier, P. M. Dixon and others.

CURRENT RESEARCH ACTIVITIES

Hedayat: It is clear that you really have not retired. What are you working on now?

Federer: It is true that I have retired only from administration, meetings and teaching, but not from statistical research and consulting. My research activities have continued as indicated by some of my current research projects, which include:

- Documentation of the toolkit Gendex, jointly with developer Nam-Ky Nguyen (Design Computing, Australia).
- Spatial analyses and exploratory model selection for spatially arranged experiments, jointly with Jose Crossa (CIMMYT, Mexico).
- Fractional combinatorial treatment design, jointly with Damaraju Raghavarao (Temple University).
- Complete sets of sum-of-squares orthogonal F squares of order n with Hosh Pesotan (University of Guelph, Canada) and B. Leo Raktoe (Singapore).
- Mixed model anomalies in computer packages, jointly with Russell D. Wolfinger (SAS Institute) and Walter Stroup (University of Nebraska).
- Fourier versus polynomial regression for field experiments, jointly with Murari Singh (ICARDA, Syria).
- Construction and analyses for augmented lattice square experiment designs.
- The two formulations for variance components for mixed models, jointly with Kaye E. Basford (University of Queensland, Australia).
- Application of the Kalman filter for statistical analyses, jointly with B. R. Murty (Indian Agricultural Institute).

Hedayat: You are working on so many different topics with so many different people. How do you find the time and energy to do all this?

Federer: When one has colleagues who are very capable and willing to cooperate, it is relatively easy to have several projects going on at the same time. I am near my limit now. I seemed to be blessed with the ability to have several things going simultaneously rather than doing only one project at a time. Also, I sometimes feel the energy and enthusiasm of my cooperators. I have been blessed with a very inquisitive mind and really want to know the answers. This creates a driving force within me to know more.

OTHER COLLEAGUES

Hedayat: Name some people in your life who have influenced your statistical thinking.

Federer: Many people, past and present, have influenced my statistical thinking and direction over the years. The scientific method has dominated my way of thinking and any scientist who actively pursues these principles has an influence on me. An inquisitive mind is an important trait for a statistician. Also, my elementary school teachers, Miss Butcher and Miss Jacque Folck, and high school teachers, Miss Cooper (Latin), Miss King (English), Miss Sweeney (algebra), Miss Ferguson (geometry), Mr. Snow (history) and Miss Schwab (social studies), influenced me considerably with their dedicated and scholarly approach and activating an inquisitive mind. These people whetted my appetite for knowledge. Aubrey C. Hildreth (Director of the Cheyenne Horticultural Research Station), LeRoy Powers (a genius type), Warren Leonard (a truly great teacher), Arnold J. King (a very creative individual and excellent administrator), George F. Sprague (a genius type), George W. Snedecor (an excellent teacher), William G. Cochran (a genius type), Alexander Mood (a great Ph.D. chairman), Oscar Kempthorne (an experimental design expert), Marvin Zelen (an inspiring and creative colleague) and Douglas S. Robson (a genius type) had considerable influence on my statistical thinking. Some other professors who influenced my thinking patterns were Barr (plant physiology, CSU), Johnson (organic chemistry, CSU), Painter (host plant resistance, KSU), DeVries (German, ISU) and Cooke (modeling, Cornell University). There are others but these are the ones I think of now.

Hedayat: You list one of your students, Douglas S. Robson, as a person who influenced your statistical thinking. Do have further comments on this?

Federer: Doug Robson is the kind of person who influences anyone with whom he comes in contact. When he first arrived at Cornell in 1949, I asked him to review a book on sampling. He found the book to be about one-third correct. He gave a seminar on a paper in *The Annals of Mathematical Statistics*. He found the paper to be mostly nonsense. Professor Jacob Wolfowitz was infuriated by the fact that such a paper would ever be published, let alone in the *Annals*. When I nominated him for a Cornell University Graduate Fellowship, I was told that the committee said, "Give Robson a fellowship. Now let us look at the other candidates." Interaction with Doug was such a joy as he could always go right to the nub of a problem and present it in a clearly understandable manner. He was a great research consultant, and consultees responded very favorably to him.

Hedayat: Since you are interested in the construction of experimental designs, have you or your colleagues discussed Euler's Latin square conjecture?

Federer: It has always been my hope and thought that mathematicians would develop a geometry for all numbers, something like a single-degree-of-freedom geometry, which would consider all numbers. My development of sum-of-squares orthogonal complete sets of F squares of order n is a step in this direction. I suspected the Euler conjecture was false and Professor Esther Seiden told me she proved this in the late fifties. We wanted to include her original material in a monograph we coauthored with several other individuals (Federer et al., 1970). She was unable to find her original notes on this when the paper by Bose, Shrikhande and Parker (1960) appeared, disproving the Euler conjecture.

FORCES AND TRENDS IN STATISTICS

Hedayat: In the early development of statistics in other countries such as England and India, agriculture seemed to have been a driving force in its development. What are your comments on this?

Federer: Agricultural researchers encounter considerable variation in their experimentation. When differences in items of interest, say treatments, are large, variation is less of a concern. When differences in treatments become smaller in relation to variation, this causes concern for the researcher. Hence, a need for better experimental designs and statistical methodology was expressed by the early Rothamsted Experimental Station (England) researchers and experimenters elsewhere. This need was answered in

part by such statisticians as Pearson (Karl), Gossett (Student), Fisher, Wishart, Saunders, Yates, Cochran, Mahalanobis and Panse. Their research aroused the interest of many other statisticians and this was very healthy for the whole of statistics.

Later on, the need for statistical procedures related to product improvement, pharmaceutical, marketing and medical research were in demand. Demands for better statistical methodology supplied the need and, hence, were a driving force for the development of statistical procedures, whether for design or for analysis.

Hedayat: Are you satisfied with current trends in statistics?

Federer: In the fifties, I predicted that within ten years, the major theme at the annual statistics meeting would be deterministic and stochastic modeling. It still hasn't happened. Operations research meetings do have presentations on deterministic modeling. I believe that only a small fraction of the material in *The Annals of Statistics* and *The Annals of Probability* ever gets into practice or into statistics courses. I have some 20 papers in *The Annals of Statistics* and realize that *Annals* papers are used mostly to write other papers. I would like to see much more emphasis on sequential methods and on stochastic modeling in published papers on statistics. I believe that statistics today is very weak in the philosophical area. For example, what is the nature and meaning of the term error mean square and random variation? Measurement theory and philosophy are very weak; for example, when is a measurement a zero and when a trace, and how does one score death of a seed versus 100% dormancy? In light of the advances in computing, I do not consider that there is an up-to-date text in experimental and treatment design or in statistical methodology. I believe that the computer can be a great teaching tool, but do we really know how to do this? The statistical profession is much better in statistical methodology and inference than they are in the planning of experiments. I think pooling is an unsung hero of statistics. It enters statistical procedures in many ways. For example, an error mean square is a pool of several sources of variation; in hypothesis testing of null and nonnull, there is a large pool of hypotheses in nonnull; in fractional replication the aliasing structure pools several effects together; a pool of effects in a mixture results when only one response is available; pooling laboratory samples for analysis can increase efficiency considerably. Despite this widespread appearance of pooling, where is it discussed in statistics courses? If statistics really is to be the language of science, much more of statistical research needs to be devoted to subject matter problems that occur in everyday experimentation rather than merely extending or generalizing results of previous works.

Hedayat: You used the word "pooling" several times in the last question. It reminds me of meta-analysis. What are your views on meta-analysis?

Federer: I consider meta-analysis as a new name for an older procedure, that is, combining results from experiments. Fisher, Wishart, Cochran, Yates and even my Ph.D. dissertation considered combining and summarizing the results from many experiments. There was considerable interest among such individuals as W. G. Cochran and John W. Tukey in preparing a book or monograph on this topic when it was broached. The reason this wasn't done was probably due to me not pushing it.

Hedayat: Do you appreciate data mining?

Federer: Data mining, as I understand it, seeks to find patterns and explanatory variables in data sets. Any method that extracts information from a data set is useful and is worthy of consideration. I consider some of the investigations I do as data mining. In particular, when using exploratory model selection for a spatially designed experiment, I am searching for a model that fits the spatial pattern present in the experiment. With the availability of the computing power we have, data mining techniques are feasible. I haven't investigated this idea very far, but I believe that statistical design, especially fractional replication, has a role to play in data mining. A method needs to be devised for finding the group of parametric vectors that allows estimation of effects for a given data set.

Hedayat: What is your view on the development, role and health of statistical design of experiments?

Federer: I have no formula for getting statisticians more interested in statistical design. It is a mystery to me how one can make inferences from a set of numbers when the sampling procedure and the population structure are unknown. Any such inferences can only have assumed populations and sampling procedures. The circular statement "these results apply to the population from which the sample was drawn" is used in statistics classes to support inferences. A statistician gets away with such a vague and often unfounded statement in the classroom, but the investigator cannot as he or she lives in the real world. The results of an investigation usually need to be put into practice. I do not believe the statistical profession, in general, is very healthy with respect to statistical design. I have

always thought that statistical design and sampling from populations should be the first courses taught, but all elementary courses I know of start with statistical methods or probability. To me, this is putting the cart before the horse! Thus statistical design, which includes a description of the target population, has a vital role in the teaching of statistics.

With respect to development, many unsolved problems remain. These will continue to arise as investigations into the unknown continue. New results often indicate the need for new methods. A recent book by Altan and Singh (2001) indicates the scope of work going on and related problems. D. Raghavarao and I have a marketing design that allows estimation of competing effects of n items in a display. However, we know little or nothing about alternative designs or properties of such designs. The field of fractional combinatorials is in its infancy and requires considerable research to bring this field to the level of fractional replication of factorials. How much do we know about sequential design of experiments? I believe the most needed book today is *The Planning and Design of Computer and Simulation Experiments*. I think it will need to be a joint effort of computer science and statistical design experts. In this century, many investigators will want to run a computer experiment or a series of experiments prior to conducting an actual experiment.

Hedayat: What do you think the role and leadership of professional statistical societies should be?

Federer: Professional statistical organizations have performed and are performing valuable services to the field of statistics through the holding of regional and annual meetings. The presentation of invited and contributed papers and panel discussions is an incentive to statisticians to do statistical research. They provide the statistical advice requested by government agencies. Such programs as Careers in Statistics have done much to further the cause of statistics. The American Statistical Association has taken on the role of a mother organization and has spawned several societies and journals that meet the needs of the statistical profession. I believe they have met and are meeting the needs of the statistical community.

Hedayat: Your visibility has been mostly through research and less so through administrative contributions. How far has that been a deliberate choice?

Federer: Research has been a definite choice on my part. In fact, when I was appointed Professor at Cornell University, I asked for and received a letter stating that half of my time could be devoted to research. After my appointment, I found out that half time meant evenings and weekends!

MISCELLANEOUS

Hedayat: Would you list ten courses (topics) that current Ph.D. students in statistics should take?

Federer: As we all know or should know, statistics is (i) the planning and design of investigations, (ii) statistical methodology for summarizing the results of an investigation and (iii) making inferences from the results of the investigation to the target population. Any curriculum that does not include courses in all three phases of statistics is deficient. Therefore, courses in statistical design and survey and laboratory sampling, courses in statistical methods, and courses in probability and inference should form the core of the curriculum. Of course, a heavy dose of mathematics is also required. The courses should be of the 21st century type, making use of available computer technology. I do not know of an up-to-date design of experiments, design of sample surveys and statistical methods textbook that makes full use of available computer technology. For example, a statistical design text should have material on computer packages for creating optimal or near-optimal statistical designs. Tables of statistical designs are inadequate and completely outmoded by available computer software. There is no need to spend time constructing and preparing a randomized form of a plan when a package can obtain randomized plans in a fraction of a second.

Hedayat: What is the role of graduate students in the success of a department of statistics?

Federer: Having competent graduate students is vital to the success of a department. The quality of the research in graduate dissertations is a reflection of the department. Having strong minors in biometry and statistics reflects very favorably on a department. I have been blessed with some very gifted graduate students such as Douglas S. Robson, Prasert Na Nagara, Anne Ebner, G. F. Atkinson, B. Leo Raktoe, A. Hedayat, John Mandeli, Barbara Grimes, Ronald Kershner, Anila Wijesinha, M. Shafiq and U. B. Paik. I consider their dissertations outstanding even if some never continued their research efforts after leaving Cornell. Douglas S. Robson chaired more majors and minors than I did. The three of us, Robson, Searle and myself, were committee members of many students minoring in biometry and statistics. Many of these went on to become full-fledged statisticians.

Graduate students and support of graduate students is a necessity for the efficient functioning of a department of statistics. Teaching and research assistantships are a necessity. They afford a competitive advantage

in attracting students into the graduate program. Graduate students are very efficient costwise and they can perform many technical functions that would otherwise have to be performed by high-paid faculty. Administrators who do not appreciate these facts need to be convinced.

Hedayat: Some of our eminent statisticians have passed on. Would you wish to comment on a few you have known?

Federer: In my mind, Sir Ronald A. Fisher is the greatest statistician of our times. His creativity and ability to set the foundations of the statistical field are unparalleled. He covered the entire spectrum in one way or another. The talk and paper by Savage (1976) "On rereading R. A. Fisher" stirred a lot of discussion of and appreciation for Fisher's work, even to the presentation at Cornell of a semester course on two of his papers. A second person who comes to mind is John W. Tukey. John was adept in several fields of inquiry. His logic and creativity were marvelous. For his impact on the entire statistical profession, George W. Snedecor had a very profound effect. Two individuals who had considerable impact on the direction of statistics in the United States are Arnold J. King and Gertrude M. Cox through their administrative prowess. Many conveniences statisticians enjoy today are due to such people as Snedecor, King and Cox. W. Edwards Deming was a remarkable man who had a terrific impact on manufacturing worldwide. Another person who had considerable impact on the use and usefulness of statistical procedures was Frank Yates. Many creative ideas are embedded in his writings. William G. Cochran was unique among statisticians for his creative and insightful approach to solving many problems in statistics. Even though theoretically well grounded, he could see the usefulness of his research in practice. Chester I. Bliss also comes to mind as a very important figure in statistics. His dedication and contribution to procedures for biological analyses were groundbreaking. Of course, when one thinks of this area, the name of David J. Finney must be mentioned also and as well as for his many other contributions. Morris Hansen had significant and lasting effects on governmental statistics, especially in the Census Bureau. There are numerous other individuals whom I knew who have made significant contributions to our field, but I was told to limit my selection. Knowing and associating with such individuals as the aforementioned was a great inspiration. I have many pleasant memories of associations with the above as well as with several others who have passed on.

Hedayat: You have written a few books. What are some of your thoughts on writing books?

Federer: I find it fun to write papers, but a wearisome, tedious and time-consuming task to write a book. My first book in 1955 took me approximately four years to complete. When I was at the Pineapple Research Institute in Honolulu in 1954–1955, one of the staff asked me how much money I expected to receive from my book. I gave her a number and then she asked me how long it took me to write the book and I gave her a number. She then said, "Oh that would be $30 an hour. No, $3 an hour. Oh no, three cents an hour. Heavens, man, you are crazy!" I feel that writing a scholarly book usually means not much money in royalties. One usually needs to write a book for enjoyment or for the feeling of accomplishment rather than monetary gain.

My 1993 book required several years to complete as it was difficult to change my way of thinking from standard statistics to the statistics of mixtures. One of my students, Anila Wijesinha, helped me considerably to clarify the concepts. It was she who suggested that we do two crops in a mixture before tackling three or more crops as I did in Volume II. She decided not to coauthor Volume I with me as she had other interests at the time. Volume II required an additional four years to prepare after Volume I was published. Some of the work for Volume II had been done in previous years.

The first edition of my 1991 book was written over a period of years for the class "Statistics and the World We Live In." This course was an artsy statistics course in that statistical concepts rather than statistical methodologies were emphasized. The second edition of this book took a year to write.

I have a bit of advice for young professionals who are vying for tenure. Writing a book is very time-consuming. This means that if one is writing a book, the number of papers one publishes will be diminished. Since number of publications counts for tenure, one should remember that a book is only one publication. It is suggested that book writing be delayed until after tenure has been received.

OTHER INTERESTS

Hedayat: I know you have many personal interests beyond statistics. Tell us about them and also tell us whether or not they had any impact on your profession as a statistician.

Federer: Growing up on a small ranch near Cheyenne, Wyoming, I did a lot of "cowboying." I was

a cattle drover for neighbors from six years old and on. I "broke" many horses to ride. I never did learn to ride a bicycle as I was riding horses too much of the time. A model-T Ford was my first car at the age of 12. It was purchased for $5 from proceeds of my work as a drover. The experiences on the ranch led me to become a professional rodeo rider for six years. My specialties were bull riding, bareback riding, saddle-bronc riding and the wild horse race. I was a very frequent winner in the last event as I knew how to select a horse that would run and would not spend too much time bucking. I rode in the first college rodeo held at CSU in 1936, winning three firsts, three seconds and the grand field prize. This ended my rodeo days. I did play football at CSU for three years, wrestled and ran track. From the time I was a small boy I played baseball and later softball, continuing up through my days at ISU. I played some softball at Cornell. I coached Little League baseball and ice hockey from 1961 to 1970 with some first place (also some last place) teams. I always enjoyed dancing of any form. Starting as early as age 13, I did square dancing, then a lot of ballroom dancing from my high school days up through my Cornell days. I have danced to a large number of the name big bands from the thirties through the fifties. About a dozen years ago, I took up tap dancing and really enjoyed it, but a torn meniscus in my left knee made me stop in 2001. And then there are golfing, gardening and skiing. I love downhill skiing, but have settled for cross-country. I first played golf in 1942 and am still playing; no par shooter, however. Every summer I play golf in a senior league here in Ithaca and exercise and lift weights the year around. If there were more time, I would play tennis and racquetball and go fishing and canoeing.

FINAL REMARK

Hedayat: What is the interplay for you between research, consulting and teaching?

Federer: The three components—research, consulting and teaching—are considered to be extremely important for any statistics department. Leaving out any one of them greatly reduces the effect of the other two. There is considerable interaction among these three components. In the course of statistical and research consulting, many unsolved problems for statistical research topics and many unique examples useful in teaching come to light. I consider myself as a research consultant and not only as a statistical consultant, and am still active in this area in the department. During consultation, a proposed research project may be altered, and many times was. As D. S. Robson and I have always said, we get many of our research ideas from statistical consultations. I have always considered statistical consulting as the extension part of statistics, that is, extending statistical ideas to scientists. It can also be considered as statistical tutoring. Researchers are in need of statistical help and having a consulting service available for them is a valuable asset. I believe that statisticians who do consulting should not consider it as a one-way service, but as a two-way valuable exchange of information. This raises the value of consulting to a higher level than just a service.

Research is a necessary and important part of any statistics degree program. If the faculty is weak in research efforts, the dissertations will likewise be weak. Turning out poorly qualified graduates reflects badly on a department. Research publication is a necessity for taking another position. Ordinarily, statistical consulting and teaching ability are not sufficient conditions, albeit usually necessary, for promotions or appointment to a position. Publish or perish is almost a law in the academic world.

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