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C. R. Henderson: Farm Boy, Athlete, and Scientist

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ABSTRACT

Charles R. Henderson was proud to be a product of a farm in Page County, Iowa. He was a one man track team in Coin, Iowa, and a brilliant student. He became a world class competitor in track at Iowa State College and, at the same time, compiled a top academic record. His early experiences set the stage for the exceptional contributions of his animal breeding career, which did not begin until he was nearly 40 yr of age, but which spanned 40 yr when he was the acknowledged leader in development of statistical methodology applied to animal breeding. His career goals were to find the best possible ways to analyze data and to provide the best genetic evaluations to the livestock industry. If the best could not be done because of computational limitations, then he would pragmatically work to find the best way that was possible.

Only his interest in Cornell hockey overshadowed his enjoyment in listening to classical music. He was an avid sports fan, especially for the St. Louis Cardinals or any midwestern team against the New York Yankees. Midwestern trips during the weeks when the Drake Relays were held were as often as possible.

Henderson's acknowledged scientific hero was Jay L. Lush, with whom he studied during his Ph.D. program at Iowa State College and with whom he shared similar talents and the intuition that made both of them leaders in the field of animal breeding.

(Key words: Henderson, C. R.; biography; mixed model equations)

Abbreviation key: ISC = Iowa State College.

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PAGE COUNTY AND IOWA STATE COLLEGE

The farm upbringing and athletic ability of his youth seem to have interacted with his outstanding intelligence to provide the synergism that enabled Charles Roy Henderson to become the foremost quantitative animal geneticist of his time.

Those who worked with him as peers and colleagues knew him simply as "Chuck". Most of us who had him as the chair of our graduate committees have difficulty thinking of him other than as "Dr. Henderson" or in our notes as "CRH". Similarly, Jay L. Lush was always Lush to Henderson.

Charles Henderson was the first child of Arthur James and Maud McMichael Henderson. He was born on their farm in Morton Township in Page County near Coin in southwest Iowa on April 1, 1911. He was forever proud of Page County and never forgot his farm background. The Henderson farm raised dairy cows and pigs, and farming was done with horses. Henderson was active in both 4-H and Future Farmers of America, being named State Farmer of the Year and being a member of the state championship livestock judging team (see Appendix).

As well as being an outstanding young farm boy, he was at least as outstanding in sports. As noted in the Cornell Necrology, at a Page County Farm Bureau picnic he entered and won the races for 12 and under, 14 and under, and 16 and under. The next year the races were for ages of 10 to 12, 13 to 14, and 15 to 16! At Coin High School, he was known as a "one man track team". (His brother, Bruce, told me that was not quite true as there were also other good athletes in Coin at that time.) Basketball of that time had not evolved beyond the center jump after each score. Henderson was the center of the front line featuring a year younger brother and a cousin who no doubt dominated the gyms of the late 1920s. His other sport of note was softball, which, for a good Methodist,

could not be played on Sundays as Henderson well remembered.

No doubt he was a top student in his Page County schools but I have no records for that. His college entrance units show four for English, two for Latin, two for history and civics, 2 1/2 for mathematics, two for agriculture, one for physics, and two in the miscellaneous category.

His track career continued at Iowa State College. The highlights include a relay (4 by 220 yards) indoor world record of 1:31.8 s in 1932, an Iowa State field house record in the indoor 440-yard run of 51.7 s in 1933 that stood for 30 yr, and an outdoor best at 440 yards of 48.6 s also in 1933 when the world record was 47.4 s.

The academic record of Henderson is documented in his Iowa State College (ISC) transcript, which foretold his accomplishments that I think are unsurpassed by any animal scientist. That transcript came to my attention when I complimented Kenneth L. Turk (the head of Animal Science at Cornell from 1945 to 1963) during my farewell seminar in 1988 at Cornell for having the vision to hire Henderson in 1948. His comment was that the reason was obvious, "He had the best d---d transcript I ever saw." And this was 40 yr after he saw it, and he probably only saw it once! That statement recalled another I heard in 1962 at Pennsylvania State University where Henderson had sent me to a meeting of the American Institute of Biological Sciences. The small statistics session was attended by A. E. Brandt, famous for his work with change-over designs, who, on finding out I was working for Henderson, said with pride that "Henderson was the best student I ever had." The first class that featured Henderson as student and Brandt as teacher was an introductory mathematics class in 1930 after which Brandt encouraged Henderson to take more math classes, which he did, including a calculus class with Brandt in 1932. How many of us remember the best student in our classes of 30 yr earlier!

Henderson graduated in 4 yr with the highest average in agriculture. His wife, Marian, recalls her husband telling her that only a student in engineering had a higher average in the whole college that year. As we briefly note the highlights of that academic record, we should remember that in addition to a full

course load, Henderson was running track in both the indoor and outdoor seasons, was a member of the college livestock judging team, and worked his entire way through college at numerous jobs, including waiting tables at the dining room of the women's dormitory.

Iowa State College (not until much later Iowa State University) was then on a fall, winter, and spring quarter system. His transcript for the first three quarters shows what an outstanding recruit ISC had gained. At the end of the 1st yr, in addition to the grades of 96, 98, and 95 in chemistry, Henderson had received three of only four grades less than 90 that would appear on his record. After that impressive 1st yr, his record only improved. Mathematics was his strength but other courses fared as well. The reason for Brandt's statement and memory can be seen in the math transcript. Of seven courses, his lowest grade was 98 and he received 99 in Brandt's Math 13 (the best grade Brandt ever gave) and a 98 in his calculus class! No wonder that Turk and Brandt remembered Henderson.

Was Henderson perfect? Not quite. He slipped to above average levels in some areas. He had one English grade of 88, a botany grade of 87, and a farm shop grade of 87. The farm shop class must have been somewhat of a trial for the mathematically inclined young Henderson. His wife, whom he had not yet met, remembers hearing about that course more than 10 yr later. For a farm boy, public speaking is usually a more traumatic experience than farm shop. I suspect it also was to Henderson and, although he never mentioned it, I'm sure he was proud of the 85.

Many of us remember Henderson's not necessarily complimentary comments about "true type". Therefore, I pulled out his record in Livestock Judging: 95 in the preliminary course and A for the judging team performance. When his attitude toward judging changed, I do not know, but it may have been during his postgraduate studies. Note, however, that the same term he took Livestock Judging, his grade (in the field he was much later to dominate) was 97 in the spring of 1932 following a 95 in General Genetics in the winter. After his junior year, ISC apparently converted to a letter system as the A for judging indicates. Quite frankly, the 98s and 100s are more memorable than the A letter grades. Again,

recall that this record was compiled while he was also working and running track.

On graduation with a B.S., Henderson continued as an M.S. student in animal nutrition. Courses in reading German and in advanced chemistry during the last two quarters as an undergraduate suggest that graduate school was not a last minute idea. Grades earned in graduate school seem logically to fit here: of particular interest in the M.S. program are the 10 h of A in statistics and 17 h of B in nutrition research. More about this "lucky" break for the field of animal breeding later. The Ph.D. record reinforces Turk's strong statement. Remember that Henderson was now not running track but was a graduate fellow with a wife and small son and already 35 yr of age. What should be noted well are that he completed a Ph.D. program in 2 yr and earned 18 h of A in advanced statistics. No wonder K. L. Turk and Jay L. Lush were impressed.

Perhaps here is a good place to include some lengthy excerpts of Lush's letter recommending Henderson for the position at Cornell. The letter shows Lush's deep insight for the qualities and habits that Henderson was soon, and for 40 yr, to exhibit.

Charles R. Henderson is one of the ablest men we have ever had in his intrinsic ability and in addition already has a broader field of experience than most men of his years ever get. I don't think we average getting as likely a prospect as him once in five years.

By nature he loves statistical analysis perhaps more than any other one thing. His eyes fairly shine when he thinks he sees a new way to analyze an interesting problem. He is keen and tireless about this. In short he is a natural research type, especially for statistical analysis of data pertaining to livestock.

About the only criticism I could possibly offer of him in this field is that he is interested in each new thing which comes along and may sometimes be in danger of laying a problem aside when he has it solved to his own understanding but before he has quite completed preparing it for publication. If he does this it would be only because he is intensely interested in some new or side problem which has come up in connection with solving that one. This isn't serious, as the large number of publications he has will attest. However, it is I think the only general point on which you would need occasionally to counsel him and occasionally help him shift his energies to where he would accomplish the most for his profession and for the public generally.

He will make a good teacher I am sure, from the very useful way in which he helps the other graduate students along. However I do hope that whatever position he takes will give him opportunity mostly for research as it is in that direction his talents are most extraordinary.

After reading that letter, I wanted to ask Turk whether and how often he counseled Henderson on the need for publication. When I finally asked, I was told by Turk that he had probably not counseled him enough.

The other letter of recommendation was from a senior nutritionist who had served with Henderson in the nutrition section of the Sanitary Corps. The letter is short with seven short but explicit sentences. It ends: "I would rate him superior in all respects. Sincerely yours, John B. Youmans, M.D. Dean" with letterhead of University of Illinois, College of Medicine, Chicago.

SERENDIPITY

Many successful careers are marked with points at which a different turn would have led in a different direction. Those of us in animal breeding, animal science, and statistics are fortunate that those turns in Henderson's life led our way. The turning points are no doubt many. Only those that seem most obvious to me will be listed here.

Suppose that the young Henderson, rather than attending ISC, had gone to Simpson College, as had many of his cousins, to study mathematics as he was ready to do until the summer of 1929. After all, at that time none of his family had gone off to the state college. Whether by chance or from inside knowledge, Dean H. H. Kildee of ISC visited the Henderson's in the summer of 1929 and persuaded him and his parents that he should attend ISC. In any case, Henderson enrolled at Ames in the fall quarter of 1929, after a year of earning money for college, with the results we have already detailed.

Serendipity is also much involved in home life as well as professional life. After staying 2 additional years at ISC to complete work for an M.S. in animal nutrition, Henderson took the position of County Agent in 1935 in a county that neighbored Page County. In the summer of 1939, he was asked also to become a district land use planning specialist so he

enrolled for 8 credits of economics in the summer session at ISC. A fellow county agent, one county nearer to Ames, asked if his daughter, a teacher working on her M.S. degree, could ride with him to Ames. A little more than a year later, on December 21, 1940, that daughter, Marian M. Martin, was married to Charles R. Henderson in Chariton, Iowa. Although Marian was prepared to be the wife of a county agent, they soon moved on to Ohio University in Athens, Ohio.

In 1942, Henderson volunteered and was commissioned as an officer in the Sanitary Corps of the US Army. His commission and assignment to the Nutrition Division likely resulted from his M.S. in nutrition. Without the M.S., he would not have been assigned to a research group and without the experience and interest he gained as the group's unofficial statistician, he may not have returned after the war to Iowa State to study animal breeding. Why animal breeding and not nutrition? Iowa State was in 1946 well known for both, but in 1933 Lush was relatively new to Iowa. The anomaly of Henderson's B grades in nutrition research may indicate some lack of rapport between student and advisor, which led to thinking about a change. That plus the stimulus of statistical design and analysis in the nutrition section of the US Army may have played a role in the decision. Lush was, at that time, already highly thought of by Henderson, as related by his wife. She also had heard that the nutrition advisor was not easy to get along with. The few mentions I recall Henderson making about his M.S. program also were in the same vein. Again, a gain and a loss: a gain for animal breeding and the world and a loss for animal nutrition.

Henderson gave credit for his development of his mixed model equations, which he first called maximum likelihood, to a problem given by Alexander M. Mood in his course on mathematical statistics. The question appeared later in the first edition of Mood's text book *Introduction to the Theory of Statistics* (15) as question 23 for Chapter 8 on page 164:

Suppose intelligence quotients for students in a particular age group are normally distributed about a mean of 100 with standard deviation 15. The I.Q., say x_1 , of a particular student is to be estimated by a test on which he scores 130. It is further given that test scores are normally distributed about the true I.Q. as a mean with standard deviation 5. What is the maximum-likelihood estimate of the student's I.Q.? (The answer is not 130).

Henderson remarked later and often that he realized this was the same as the most probable producing ability problem of Lush. In fact, the answer (I.Q. of 127) is obtained easily from selection index principles that Henderson did so much to establish.

Cornell University was the place to come in 1948 for an innovator in animal breeding. In Turk's words (19): "He was the right man for the right job at the right time." That confluence is discussed in this symposium by Gene Freeman (1). What are some of the turns that led to a position being open at Cornell? When F. B. Morrison stepped down as head of the Animal Husbandry Department, Turk, who had returned from the University of Maryland in 1944 to succeed Professor E. S. Savage, became head of the department in 1945 (19). Soon thereafter, Glenn Salisbury, who, although most well known as a reproductive physiologist, was also responsible for teaching and research in animal breeding and genetics, left for the University of Illinois. The department decided to obtain what Turk called "better balance" in its programs (19). The new direction resulted in hiring C. R. Henderson.

Another major turn occurred when Henderson became eligible for his first (and to be only) sabbatical leave. Arthur Ward, head of the herd improvement division of the New Zealand Dairy Board, after a visit to Cornell in 1953, and Olive Castle, its chief statistician who met Henderson in Ames in 1952, encouraged Henderson to visit New Zealand. In 1955, he was awarded a Fulbright Award for research in New Zealand, where he first met Shayle R. Searle, who later became his Ph.D. student and faculty colleague in biometry at Cornell. Henderson is rightfully given credit for introducing matrix algebra to animal breeding. Matrix algebra was introduced to Henderson by Searle, who had just started as Research Statistician working with Olive Castle. We all know where that has led in terms of BLUP and mixed model equations. In fact, Searle helped with the matrix proof of the equivalence between BLUP and solutions to the mixed model equations, called maximum likelihood at that time. Henderson's first extensive use of matrices in a paper seems to have been in the proceedings published in 1963 of the 1961 Symposium on Statistical Genetics and Plant Breeding (6) in which many properties of

selection index and the "maximum likelihood" procedure were described. As some of us remember, acceptance of matrix algebra by animal breeders was about as rapid as acceptance of young sire sampling by bull studs. Nevertheless, matrix algebra is now nearly as universally accepted as a required course for would-be animal breeders as are young sire programs by bull studs.

QUESTIONS, IRONIES, AND PUZZLES

Henderson's Ph.D. thesis was duplicated and studied by many generations of animal breeding graduate students at Iowa State. Despite its influence, I cannot find any evidence that the material was published. An abstract (3) does appear in the proceedings of the 1949 annual meeting of the American Society of Animal Science with a title that matches the description of the thesis project he described in his application letter for the position at Cornell. Some of the material may also have found its way into the chapter (4) he wrote for *Heterosis*, a conference proceedings published in 1952. L. N. Hazel (1990, personal communication) explained that the major contribution of the thesis was "in the analytical methods Chuck developed, not in the results themselves. Since it [the data] was from a regional project, several stations later pooled data which were published by Bereskin". The preface to his book, *Applications of Linear Models in Animal Breeding* (12), which I reread in preparing this paper may give another reason. In the preface, Henderson states that in his first few months at Cornell, he had worked out the basic principles behind what we now call the mixed model equations. For example, his paper at the 1949 annual meeting of the American Dairy Science Association described what he then called the maximum likelihood method to obtain annual corrections for herd environment for predicting breeding values of cows, for estimating genetic improvement in a herd, and for computation of age correction factors (2). He seems to have simply moved on to a more correct approach and would obviously not have wanted to publish procedures from his thesis that were not as good as those he had more recently discovered, procedures that have now spread around the world.

Lush Descendant

Henderson rightfully described himself as an academic descendant of Lush. However, at ISC he officially was under the guidance, at least for his final year, of a new faculty member in swine and beef breeding, Lenoy N. Hazel, who came to ISC the winter after Henderson returned for his Ph.D. He published papers with neither, perhaps because he developed his methods on his own but also perhaps because his thesis material was not published in a scientific journal. Neither I nor his wife know of any friction with Hazel. Hazel wrote (1990, personal communication) that "We [he and Lush] divided graduate students according to their major species interest . . . Lush always felt a major responsibility for all grads" and that the division of students "was somewhat a paper ruse to quiet a graduate dean who felt one man could not guide the work of so large a number of students. In some ways, I was closer to the students, being nearer their age, but he was always the major professor and taught the graduate courses." He continued, "Chuck became my student largely because we had accumulated 10 years of very messy data on different rates of inbreeding in swine, and his interests made him an ideal choice for that responsibility." Mrs. Henderson does remember that Henderson admired Lush even before he returned to ISC in 1946 to work for the Ph.D. Lush had handled the admission and signed the course registration cards for the first year. Hazel was listed as chair of his graduate committee for the preliminary and thesis exams.

The "Age" Question

An irritant to Henderson as he approached the nominal age of retirement was the idea that older scientists were generally not considered to be productive. His career in animal breeding certainly refutes that idea as well as the one that the most creative and innovative period for many people occurs by their early 30s. Henderson did not become an active participant in the field of animal breeding until he was 37 years of age. Yet he was the dominant member of that field for most of the next 40 years.

Development of the maximum likelihood procedure, later named more appropriately

BLUP, from the mixed model equations did occur early in his career—from the early days at Cornell in 1949 (2) until the selection advance and genetic progress paper (6) was given in 1961. During those years, he went from 38 to 50 yr of age! The variance component paper (5) so well covered by Searle (18) in this symposium was published in 1953, about 2 yr after it was presented. He was 40. Perhaps his most amazing discovery was the set of rules for calculation of the inverse of the relationship matrix (9, 11). In the preface to his book, he implied that after the mixed model equations this was his most important work. This discovery is the basis for the power of the genetic evaluation procedures and for estimating additive genetic variance free of selection bias (16). Henderson was 64 when that work was published in 1975.

The most complete description of the properties of his mixed model equations was written in connection with its least understood property: the property of prediction being free of selection bias when selection is practiced within fixed effects. This major paper (10) was also published in 1975 at age 64.

Other examples of major papers at ages beyond which creativity is said to be gone can easily be given, e.g., (8). One publication that should be mentioned here is his book (12) published in 1984 at the age of 73. Many new ideas appear in that book as Brian Kennedy has described in his paper (14). The last few pages anticipate a Bayesian approach to the problem of unequal genetic and residual variances from herd to herd.

As an Advisor

On reflection about Henderson as a graduate advisor, contradictory pairs of words arise. He was *undemanding* of his students, yet with few exceptions, his students were stimulated by his example and support to do their best. His athletic tendency for *competition* became apparent when students or colleagues brought a problem of interest to him. It was nearly impossible for the student or colleague to come up with a solution as quickly as Henderson. Perhaps as a consequence few students did theoretical thesis research.

He was *tolerant* of the abilities and working habits of students and colleagues. He never

criticized them for lapses from intelligent approaches or for too much time away from the job at hand. Most students flourished with that approach. A few might have been better served by timely suggestions. He, however, was appropriately scientifically *critical*.

With high eyebrows, a far-sighted intense set of eyes, and seemingly complete concentration on the yellow pad with its tracks of number 2 lead pencil, or later ball-point ink, many students were reluctant to approach him. He seemed a *formidable* person to approach. Yet I am sure Henderson felt he was completely *approachable*, and he was, once the approacher became brave enough to approach. In fact, he seemed to welcome the contact and stimulus of student discussion. However, the student had to take the initiative. Those few that did were amply rewarded by his combination of patience and understanding.

The Book

For many years a book contract hung over Henderson's view of the world—from the mid-1950s on. As described briefly later, he was until 1984 more than a little defensive about not having written "The Book". Thanks in no small part to the efforts and encouragement of the group at Guelph, "The Book" was published in 1984. The 1984 version was worth the wait. Earlier versions would not have been as complete or as important. The 1984 book was at least the fourth that was started. The early 1950s book would have been a selection index book based on his first advanced animal breeding course. During the late 1950s, the advanced seminar, which was the forerunner to his mixed model course, produced a mimeographed set of notes suitable for an introductory linear models course. Shayle Searle, the coleader of the 1958 seminar, later published a linear models book (17) that very likely drew inspiration from that seminar.

A later version of the book advanced through about 10 chapters in the late 1960s and early 1970s. That version, which I often used for matrix review, would not, however, have included the inverse to the numerator relationship matrix or the REML approach to variance component estimation. It would also not have included much on Bayesian estimation. If one of the earlier books had been

completed, it is doubtful that "The Book" would have been written later. Thus, despite the defensiveness that accompanied the 30 yr from early contract to publication, the final result is a more true legacy of the revolution Henderson's genius stimulated than any earlier version would have been.

Path Coefficients

Sewall Wright's influence on Jay Lush was great; both men were without question heroes of Henderson. Sewall Wright, however, was a leader in "path coefficients", and the core of ISC training in animal breeding for many years was based on path coefficients. Yet Henderson did not teach path coefficients; he pioneered the equivalent but definitely much easier and intuitively clear (at least to his students) method based on linear models and expected values.

Fear of Flying

The answer to the question of whether to ask Henderson to visit another country or even another state for many years was that he did not like to fly. This answer, which I often gave and which was seldom refuted when Henderson was asked personally, seemed to be correct until about 1976. I could never understand his reluctance to fly, because his duties during World War II took him island hopping all over the South Pacific by DC-3 or worse. I also recall sitting with him on a noisy turbo-prop flight between National Airport in Washington and Ithaca in 1966 (7). He did not seem nearly as nervous as I was! After his retirement in 1976, he soon became a worldwide traveler. He still preferred to drive if possible, but traveling seemed enjoyable. What had changed? Several things had changed. Perhaps the most important was that after his wife Marian had also retired, she could now travel with him. Henderson was also a frugal person. His work required little outside funding (computer time was available through the New York Dairy Records Processing Laboratory, and pencils and paper were inexpensive), and universities (Cornell especially) provided almost no travel funds. He was not concerned with grants except for a small but important continuing one from New York Artificial

Breeding Cooperative (now Eastern AI Cooperative), which did not allow expense account travel in agreement with Henderson's philosophy. Before retirement he felt a responsibility, I am sure, to his employer, the State of New York, and to his students. Travel would take time away from his work. Obviously, these ideas are speculative. I now find it impossible to believe Henderson was afraid of flying.

Mathematical, Not Mechanical

Many of the graduate students of Henderson must have wondered why someone so mathematical and so precise would find so much difficulty in wiring a computer board, in deciding which one of the two buttons on the IBM 650 to push, or in hooking up the cables for a personal computer. I have a similar reluctance and found it strange that I could help Henderson with setting up his PC, when I felt the same way. He was mathematically but not mechanically inclined, although, as his wife told me, he could do it if he had to or wanted to. I think he simply did not want to take the time to read the instructions when he knew that someone else could do the job in a few minutes with no need to repeat the operation for months or years. Another reason might be that he grew up in a nonmechanical era. Farming was done with horses; cars were rare. His brother, Bruce, confirmed that brother Chuck was not mechanically inclined.

Dogmatic and Pragmatic

Another pair of words seem to fit the philosophy of Henderson—dogmatic and pragmatic. Long before we knew how and before Henderson had converted us, he usually if not always knew the best way to approach a statistical or genetic evaluation problem. This was particularly apparent at meetings or in general discussions during which he would argue that only the best possible methods should be used. This was his dogmatic side. But when faced with a real problem and computing difficulties, he would compromise with the best available methods—his pragmatic side. He was extremely proficient in finding the best approximations, such as the herdmate comparison at the time it was revolutionary (13).

Ezra Cornell and C. R. Henderson

Although many Cornell faculty were much in tune with Ezra Cornell's motto that he would found an institution where "any person can find instruction in any subject," I always felt that Henderson practiced the Cornell philosophy better than most. The Cornell outlook naturally turned worldwide. Cornell University and its departments, perhaps none more than the Animal Science Department, after World War II felt a responsibility to help train scientists and students from around the world. Often this meant working with students who were not prepared as well as would be desirable. The Cornell system allowed such students to advance at their own pace, usually with remarkable success. Some might argue that different standards were being applied to different people. I think that the standard that Henderson set was the same for all: to let each become what he was able to become. The pronoun "he", used for convenience in the previous statement reminded me of one regret that Henderson often expressed in training graduate students. Although many women were admitted to the graduate program, none ever went beyond the M.S. with Henderson. He was exceedingly proud of the one postdoctoral fellow I remember who was a woman, Lucia Pearson Vaccaro. He often reminded us of Gertrude Cox, who taught him how to use punched card equipment at ISC and who later became famous as a statistician at North Carolina State University.

OUT OF THE OFFICE**Sports Fan**

The young athlete from Iowa retained his interest in sports throughout his life. At Cornell he was a faithful fan of most of the sports teams. His attendance at track, basketball, and football events was particularly regular while his sons were growing up. For a few years, he served as an official at one of the major winter indoor track meets in the east, the Heptagonals at Cornell (Ivy League plus Army and Navy). His interest in the Drake relays is mentioned often. Although he never attended with the regularity of one of his younger brothers, who was said to have been in attendance at 48 of 50

consecutive Drake relays, Henderson attended as frequently as possible. Several (although Marian Henderson cautioned me that there were not as many as I had thought) speaking trips that were scheduled in the Midwest in the spring were convenient for an extra day or two in Des Moines.

Among his sports heroes were two near-contemporaries: Glen Cunningham of Kansas, who had overcome near fatal burns to become America's premier miler, and, naturally, the Olympian sprinter from Ohio, Jesse Owen. No doubt Henderson admired others as well, but an unlikely sport for an Iowan, ice hockey, furnished two others. Henderson's loyalty was great to the Cornell Hockey team, which rose from a new, well-trounced team to national champions under Coach Ned Harkness. Harkness, a rather unimposing person, was a motivator who could turn good athletes into superior team players, including a national championship team with a 29-0 record. I believe what impressed Henderson more than anything was Harkness' interest off the rink in his players' success as students. The other hockey hero was an imposing athlete and scholar: Ken Dryden, baseball shortstop, dean's list student, Nader's raider, and perhaps one of the best hockey goalies ever. For example, when Dryden returned to hockey after a year of studying for his law degree, he joined the Montreal Canadians just prior to the playoffs and led them to a Stanley Cup. From the time Dryden signed with the elite team of hockey, Henderson was a fan of "Les Habitants".

Henderson's attitude toward a comparable team in baseball was quite the opposite. Although for years surrounded by Yankee fans from Nebraska, Michigan, New Jersey, and New York, he never wavered in hoping for defeat of the Yankees. Any other team was the underdog and therefore deserved his support. Although he supported with little success the Chicago Cubs, his son, Charles, has indicated that Henderson's favorite team was the St. Louis Cardinals. His interest in baseball extended itself to coaching both of his sons in the Kiwanis leagues (Ithaca's version of Little League baseball). Henderson shared many nature walks with his second son, Jim, in the Forest Home area where they lived and particularly encouraged his interest in hockey and

baseball. For several years, he would be up at 4:30 a.m. with Jim for the early Pee-Wee hockey practices at Lynah Rink.

Home

Although Henderson seldom spoke much about his family at work, he obviously was devoted to his family and was supported in his work by them. He was involved with caring for the children as they grew, with reading of bedtime stories, and with their developing interests. His wife, Marian, provided support and help that gave him extra time to concentrate on his work, for which he expressed appreciation to colleagues. In turn, he spent many hours in helping with the Head Start program that Marian directed for many years. When Marian retired from her work with disadvantaged preschool children a few years after Henderson retired from Cornell University because of the age rule then in force, she became his constant companion in their travels and extended assignments throughout North America and the world. Ithaca, however, remained their home, even though they were not often there.

Music

Henderson attributed his strong interest in music to its relationship to mathematics. His wife Marian, on my asking where or when that interest (which is a little unusual for a boy from a country school in Iowa) began, told me that the County School Superintendent, later State School Superintendent, visited his school one day with a portable phonograph. Because Henderson most likely would have told Marian that story many years later, my conclusion is that the superintendent's wind-up phonograph and its music, the William Tell Overture, must have made a very strong impression. His radios at work and, I'm sure, at home were usually tuned to a classical music FM station in Ithaca, which coincidentally also carried all Cornell basketball, football, and hockey games. The dial did not need to be changed. My impression was that his favorite composer was Johann Sebastian Bach, whom he put ahead of the other two B's, Beethoven and Brahms. Marian thinks that his favorite selection was Bach's "Air for the G String". His memorial service featured four pieces by J. S.

Bach. Son Charles told me that, although music of the Baroque era was his favorite, he also liked blues and folk music. I can remember his defending music of The Beatles. Henderson shared his love of music with his daughter Elizabeth, who started piano and violin lessons at an early age; Henderson often accompanied her to the lessons. I can remember as a new graduate student hearing Elizabeth perform a violin solo at an age of 6 or 7 at one of the regular gatherings the Hendersons held for students and professional visitors. Elizabeth continues with her violin as a hobby with a Boston orchestra. She and her father would often talk on the phone about the music the orchestra was playing and of the musical programs the family had attended.

Charles also told me his father was widely read on a variety of subjects. He seemed to be always well informed about many subjects. Whether he watched TV much I doubt, but I do remember that on most mornings he could recap what had happened on the Johnny Carson show the night before. As many of you know, "Johnny" was a Midwesterner who was born in Iowa, but whether that contributed to his allegiance to the program I don't know. I think that before Johnny Carson he watched his predecessors, Steve Allen and Jack Parr. Perhaps he was a night as well as a day person. In the east the Carson show started at 11:30 p.m., and Henderson seemed always to know who the last guest was at 1:00 a.m. Then Henderson would be at work before anyone else the next morning. He did not require much sleep.

Church

The Methodist church was an important part of the life of his parents and of the young Henderson and his brothers. After moving to Ithaca, he was a church school teacher, a member of numerous committees, and, for a time, chair of the official board of the United Methodist Church. He was very proud of the church organ, which was dedicated by E. Power Biggs.

Gardening

Why he would tease the graduate students who had gardens I will never understand, espe-

cially with his agricultural background. Perhaps it was his devil's advocacy, which often lay just below or sometimes obviously above the surface. He often had a garden and liked fresh garden vegetables as much as any of us. In any case, I would guess there are more than a few former graduate students who think of Henderson as they enter their gardens.

BACK TO ANIMAL BREEDING

More Heroes

Two of the major names in animal breeding history were Henderson's scientific heroes: Jay L. Lush and Sewall Wright. I think Henderson realized his place as an academic successor of those great people. He especially admired Lush for his personal characteristics even before he studied with him, and he was proud to have studied with him. Wright was admired for his early work and, I suspect, for his productivity after his nominal retirement. I'm sure a goal of Henderson was to be as productive late in life as they were. Although he did not live as long, my obvious bias is that he was even more creative later in life than his heroes.

Henderson often mentioned the intuition of Lush and his ability to sort out the unimportant from the important. I think Henderson felt he had the same kind of intuition; I am completely convinced. Henderson, with rare exceptions, none of which I can recall now, instinctively seemed to move to the best statistical answers to problems in animal breeding. No doubt his experiences as a county agent and during World War II helped his perspective. Nevertheless, he always seemed to be sure of what was important and what was not important.

I have often wondered whether the mixed model equations or A inverse would have been discovered if personal computers had been available. Henderson's approach to a problem generally was through a small example of the kinds that appear in his papers. The paper and pencil approach seemed to give him additional insights, especially the natural fractions that often appeared as the solutions. Would real*8 numbers have led to so many useful ideas? I doubt it.

One thing that irritated Henderson was that he felt many prospective graduate students

were advised to go elsewhere because they were told that animal breeding research at Cornell was theoretical. To the contrary, Henderson felt that Cornell research was applied; the goal of his research was to provide tools to help livestock producers. Theory was a necessity to make the application the best possible.

Publication History

The publication record of Henderson is puzzling. His army tour of duty resulted in numerous multiple author papers. After that, until about 1976, many important ideas appeared only in abstract form [e.g., the stablemate (herdmate) comparison method]. Most of the few publications were what are rightfully called major papers. Generally Henderson was the sole author. Although he was a wizard at computing techniques (e.g., his matrix package, his analysis of variance package), he rarely published a data analysis paper. Can anyone think of one? Most of his coauthored papers with students, however, were the result of data analysis. It is not known whether the paucity of papers was due only to Henderson's tendency, as Lush pointed out, to move on to new areas once he had solved a problem without necessarily publishing the solution. At about the time of his retirement from Cornell, Henderson's publication history changed drastically. Every issue of the *Journal of Dairy Science* seemed to have a new paper. Often these papers described procedures that he had been teaching for years. I remember teaching the procedure for augmenting mixed model equations with equations for animals without records before his paper was published. I had learned of the procedure years earlier in his advanced course. Although Henderson was strong in his belief in some of the mixed model procedures he proposed and used, he also seemed to have a slight uncertainty of whether what he believed to be the properties were provable. At his 1976 retirement, he may have become more confident either due to his own work or to the work of others. Simulation studies in particular always seemed to substantiate his beliefs. He also had more time available, and he, as we know, did not intend to and did not retire from animal breeding. Thereupon, he rapidly published papers that, although generally of great importance, were

often not as important as earlier papers. He may have been making sure he would receive the credit due him for those ideas before someone else stumbled onto them. This race to publication may have been a partial realization that he would not live forever. More likely, his quietly competitive nature pushed him to stay at the forefront of animal breeding—more about this later.

Writing

As is obvious from his application letter for the position at Cornell (see Appendix), Henderson wrote clearly and concisely. His papers are similarly clear, but his conciseness often frustrated his readers. He was a master of leaving out the intermediate steps of the development of an important result. What the reason was for his frugality with text, I do not know. Certainly a few more steps would have resulted in "the word" being spread more quickly, and fewer readers would have given up in exasperation—oh, those missing steps!!

Lush was known as a generous editor to his students: generous with red pencil and constructive suggestions. In fact, I often wondered whether that inhibited his students from publishing later on. Henderson, on the other hand, seemed to make few suggestions in theses. The writer, not the chair of the committee, was responsible for the style. He was, however, a somewhat strict grammarian; split infinitives, which I was often guilty of using, were pointed out kindly but firmly.

Tolerance Again

Tolerance of mere human failings was also noteworthy. Henderson did not smoke cigarettes, drink alcoholic beverages, or swear. Yet I never heard him criticize anyone who practiced those addictions. His students, however, generally were more saintly in his presence than with their peers. On what were more serious occasions, he never seemed irritated nor even critical. Three examples come to my mind. In one case, after a late night party, a student was having trouble starting his car on Seneca Street hill (one of those 45-degree inclines in Ithaca) when a policeman came along to help out. The student hadn't realized he was in the wrong car or even that he was in a car.

Henderson, in the early morning hours, bailed him out from the city jail with no further comment. On the trip to the Raleigh meeting in 1961 where Henderson presented the paper outlining the properties of selection index (6), we were several hours late in leaving Ithaca. The date was March 18, the day after St. Patrick's day. One of our riders had not awakened sufficiently for the early morning start. Henderson never said a critical word during the two-day drive. On another occasion, a student returned to Ithaca to find his possessions locked up due to some dispute over unpaid rent. The student wanted what was his and proceeded with that goal. Henderson and a local optometrist combined to smooth troubled water late at night and bailed out the determined student. Henderson, in his usual way, said not a word, critical or not. Sometime later I was having my eyes examined by the doctor and mentioned the incident. He was still angry with the student and implied that he would have let the student stew in jail for awhile.

SOME IRRITANTS

One part of Henderson's personality seemed to change over time. For many years he was verbally uncritical of other scientific work. Shayle Searle and I discussed this in working on our presentations. Never a bad word about anyone seemed to be Henderson's operating principle, although he would differentiate scientifically between what he thought was wrong and what he thought was correct. Yet as his official retirement date approached and passed, he became more vocally critical in some respects.

First notice of this was rather mild. Generally, the criticism was of papers and presentations that Henderson thought mirrored material on selection index or BLUP that he had taught for years or had published generally. This slight irritation was similar to what he expressed for those of his students who put into book form some of his ideas. These books included topics on selection index, linear models, and applied statistics. The irritation seemed to pass rather quickly and may have been due to his regret at not having written those books himself. Publication of "The Book" in 1984 seemed to resolve those petty irritations.

He was particularly unhappy with a few papers that seemed simply to be copies of what he had already published. Probably he was correct, but those other papers may have been valuable in spreading the principles Henderson had first developed and in expanding his international reputation.

A somewhat more serious change of character was at scientific meetings during his early "retirement" period. His questions and commentary following paper presentations were not always pleasant for the presenter, for the audience, and particularly for Cornellians in attendance. I have puzzled over this because it contradicted the perception I had of Henderson. If I had been a new graduate student giving a paper, I would have been more than a little apprehensive. Such strong criticism was in contrast to his tolerance of inexperienced students giving departmental seminars. I do not believe such criticism was self-promoting. He more than once remarked about the lack of interaction at meetings compared with his early days when such people as Lush, Hazel, and Gordon Dickerson would lead vigorous discussions. My belief is that he felt a responsibility to recreate that atmosphere. However, he was not comfortable with speaking out and, in his excitement, was not always diplomatic. If he ever failed at anything, this was perhaps it. The criticism was never personal, and a few minutes later he might be found in pleasant conversation with the person he had put on the spot.

A somewhat different form of criticism seemed to plague Cornell graduates. If, after graduation, they ever seemed to slip from the best ways of doing an analysis, they were likely to face stern criticism. On occasion, this criticism developed even when Henderson's methods were followed precisely, although he had thought that an inferior method had been used. I can recall one exasperated presenter asking me later, "What does he want?" I do not know the reasons for these actions. The best apology I have is that he was paternalistic with Cornell graduates and expected the best of them. Occasionally he would be so preoccupied with the idea they might not be doing their best that he would fail to see what they were doing. Again, this was postretirement, 1976 and later.

In contrast with later scientific meetings, Henderson's participation in departmental ani-

mal breeding seminars was constructive and tolerant. I would often fear the worst for M.S. students, who with typical inexperience might make an outrageous statement or more. Never in my memory were they taken to task publicly or privately. Ph.D. presentations were likely to receive vigorous discussion but always in a constructive way.

Henderson was not happy about having to retire from Cornell University due to the rule in place in 1976 of forced retirement at 65 years of age. He did not allow this disappointment to influence his work. Credit should be given to the animal breeding group at the University of Guelph and the administration and faculty at the University of Illinois for providing academic and moral support to the Hendersons from 1976 to 1989. Henderson's contributions to the science of animal breeding and to graduate student training would have been much less without that support and the support of the many other institutions that provided visiting professorships for shorter periods so that he could share his ideas and insights with a wide audience.

SUMMATION

This short, somewhat rambling, but personal view of Henderson seems to me not to have arrived at any sense of Henderson other than that he was what he seemed. He was an extraordinary man without the pretenses that some of the exceptional develop. His farm background, his quiet competitiveness, and amazing ability and intuition guided his scientific career. His last goal, I believe, was to become the elder statesman of animal breeding in the way Lush did. He attended as many national, regional, and international meetings as possible. Henderson's attendance at a meeting was generally a highlight. He succeeded in this goal as well as in the goal of remaining active and productive until the end of his life. A rather poignant statement relayed by Rohan Fernando shortly after Henderson's death was that Henderson had told him he felt the place to die was at a scientific meeting. He ran the race to the end: his death was a week before the regional meeting of the American Society of Animal Science at Des Moines, in his home state of Iowa. His slides were prepared for his presentation and because he thought he might not be out of the hospital in time to attend, he

gave them, with instructions, to a colleague, Roger Shanks, who presented the paper.

My feeling, I think shared by many, is that Henderson is, and will be, sorely missed. He was a foundation of animal breeding for so long that we took for granted that he would always be nearby and ready to help us if needed. His death caused a shadow to fall across the lives of his family and friends. The enthusiasm, insight, intuition, and freely given advice of the farm boy, athlete, and scientist from Page County will be remembered. I and many others, I am sure, are grateful for having had the good fortune to have worked and studied with Henderson and to have benefitted from his tolerance and wisdom.

His wife has found a copy of the transparency that Henderson had written for his class at Kyoto University in response to a request from his sponsor, Y. Sasaki. Henderson's own concise but accurate words seem an appropriate way to extend his philosophy of science:

Some Advice to Young Scientists

1. Study methods of your predecessors.
2. Work hard.
3. Do not fear to try new ideas.
4. Discuss your ideas with others freely.
5. Be quick to admit errors. Progress comes by correcting mistakes.
6. Always be optimistic. Nature is benign.
7. Enjoy your scientific work. It can be a great joy.

C. R. Henderson
Kyoto University
December 16, 1985

ACKNOWLEDGMENTS

Marian Henderson has gathered and provided copies of many valuable historical documents, several of which were used in this presentation. All will be saved for the future. Thanks are expressed to her for all of her efforts and to Henderson's son Charles and brother Bruce for sharing their memories with me. Susan H. Herbert is thanked for her help in gathering material. Shayle R. Searle is thanked for his ideas, facts, and constructive suggestions.

The idea for this symposium was the inspiration of George E. Shook of the University of Wisconsin, who almost singlehandedly orga-

nized and coordinated the symposium and publication of its proceedings. His "labor of love" should be recognized for its lasting contribution to the field of animal breeding.

REFERENCES

- 1 Freeman, A. E. 1991. C. R. Henderson: contributions to the dairy industry. *J. Dairy Sci.* 74:4045.
- 2 Henderson, C. R. 1949. Estimation of changes in herd environment. *J. Dairy Sci.* 32:706.(Abstr.)
- 3 Henderson, C. R. 1949. Estimation of general, specific and maternal combining abilities among inbred lines of swine. *J. Anim. Sci.* 8:606.(Abstr.)
- 4 Henderson, C. R. 1952. Specific and general combining ability. Heterosis. Iowa State College Press, Ames.
- 5 Henderson, C. R. 1953. Estimation of variance and covariance components. *Biometrics* 9:226.
- 6 Henderson, C. R. 1963. Selection index and expected genetic advance. *Statistical genetics and plant breeding*. Nat. Acad. Sci., Natl. Res. Council. Publ. 982, Washington, DC.
- 7 Henderson, C. R. 1966. A sire evaluation method which accounts for unknown genetic and environmental trends, herd differences, season, age effects and differential culling. *Natl. Tech. Symp. Estimating Breeding Values of Dairy Sires and Cows*. Washington, DC.
- 8 Henderson, C. R. 1973. Sire evaluation and genetic trends. Page 10 in *Proc. Anim. Breeding Genet. Symp. in Honor of Jay L. Lush*. Am. Soc. Anim. Sci., Am. Dairy Sci. Assoc., Champaign, IL.
- 9 Henderson, C. R. 1975. A rapid method for computing the inverse of a relationship matrix. *J. Dairy Sci.* 58: 1727.
- 10 Henderson, C. R. 1975. Best linear unbiased estimation and prediction under a selection model. *Biometrics* 31:423.
- 11 Henderson, C. R. 1976. A simple method for computing the inverse of a numerator relationship matrix used in prediction of breeding values. *Biometrics* 32: 69.
- 12 Henderson, C. R. 1984. Applications of Linear Models in Animal Breeding. Univ. Guelph, Guelph, ON, Can.
- 13 Henderson, C. R., H. W. Carter and J. T. Godfrey. 1954. Use of the contemporary herd average in appraising progeny tests of dairy bulls. *J. Anim. Sci.* 13: 959.(Abstr.)
- 14 Kennedy, B. W. 1991. C. R. Henderson: the unfinished legacy. *J. Dairy Sci.* 74:4067.
- 15 Mood, A. M. 1950. Introduction to the theory of statistics. McGraw-Hill, New York, NY.
- 16 Schaeffer, L. R. 1991. C. R. Henderson: contributions to predicting genetic merit. *J. Dairy Sci.* 74:4052.
- 17 Searle, S. R. 1971. Linear models. John Wiley and Sons, New York, NY.
- 18 Searle, S. R. 1991. C. R. Henderson, the statistician; and his contributions to variance components estimation. *J. Dairy Sci.* 74:4035.
- 19 Turk, K. L. 1987. Animal husbandry at Cornell, a history and record of development from 1868 to 1963. *Coll. Agric. Life Sci. Cornell Univ.*, Ithaca, NY.

APPENDIX

Animal Husbandry Department
Curtiss Hall
Iowa State College
Ames, Iowa
March 25, 1948

K. L. Turk, Head
Department of Animal Husbandry
New York State College of Agriculture
Cornell University
Ithaca, New York

Dear Turk:

I should like to be considered for the position in animal breeding in your department. I should particularly like to find a position offering opportunities for making the fullest use of statistical genetics as that is the type of work for which my recent training and experience best fit me. I do, however, have in addition quite a broad background in animal husbandry and general agriculture.

I was raised on an Iowa farm on which the major enterprises were dairy cattle and hogs. We were members of a Dairy Herd Improvement Association. I was a member of the 4-H and of the Future Farmers of America, being chosen as an Iowa Farmer in my last year of high school. I was a member of the state championship livestock judging team.

I received the bachelor of science degree in animal husbandry at Iowa State College in 1933. My four year scholastic average was the highest in the Division of Agriculture. I was a member of the college livestock judging team. My undergraduate electives were in chemistry and mathematics.

After completing my undergraduate work, I started graduate study in animal nutrition at Iowa State College. After completing work on my master's degree, I spent five years in the Iowa extension service as assistant county agent, county agent, and extension specialist in land use planning. From there I went to Ohio University at Athens, Ohio to teach animal husbandry and to manage the livestock enterprises on the university farm. These included dairy, beef, and swine herds, and a poultry flock. After two years at Ohio University, I spent nearly four years in the army.

My army experience was a particularly fortunate one from my standpoint as all of it

involved research in nutrition and statistics. I was commissioned in the Medical Department's Nutrition Division. My duties involved assisting with three different tests of army rations, surveying the nutritional status of troops in the Pacific theater, and conducting a year long study of conscientious objectors subsisting on a very low B-complex, animal protein, and tryptophane diet. In each of these studies, data were obtained on nutrient intake, blood and urine levels of certain vitamins, physical and psychomotor performance, and clinical signs of nutritional deficiencies. It was my responsibility to prepare all recording forms, to directly supervise the collection of nutrient intake data, and to make all of the statistical analyses and interpretations. The data from two of the tests were punched on I.B.M. cards, and as a result of this I gained valuable experience in analyzing such data. During the last half year of my army service, I was commanding officer of the Army Medical Nutrition Laboratory at Chicago. It was there that we conducted the B-complex deficiency experiment. I also assisted both there and in Washington, D.C. with the training of nutrition officers.

I have been author and co-author of a number of articles which have appeared during the past four years in the Journal of Nutrition, the American Journal of Physiology, the Archives of Biochemistry, the Journal of Investigative Dermatology, the Bulletin of the U.S. Army Medical Department, Gastroenterology, Military Surgeon, the American Journal of Medical Science, and Medicine.

If you desire to have an appraisal of my research work in the army, I would suggest that you write either or both of the following men under whom I served:

John B. Youmans, Dean, Medical School, University of Illinois, Chicago, Illinois.

George H. Berryman, Medical School, University of Chicago, Chicago, Illinois.

My present studies at Iowa State College are in the fields of animal breeding, genetics, and statistics. I am taking a joint major between the first two and a minor in the latter. Because of my interest in the subject and because of its fundamental importance as a tool in animal breeding research, I have gone much farther in statistics than is usually done in the minor field. My thesis problem involves

a study of the performance of the Iowa State College inbred lines of swine in crosses and estimates of the relative importance of general and specific combining ability of inbred lines. It requires some rather advanced statistical techniques. The duties in connection with my research fellowship give me plenty of opportunities to assist with collection of data in both the swine and dairy herds.

I have assisted occasionally with the teaching of Lush's graduate course and Hazel's undergraduate course. This experience plus my teaching experience at Ohio University has

convinced me that a certain amount of teaching is not only very interesting to me but also of value in seeing research problems more clearly.

I hope to have my thesis very nearly completed by the end of this summer but cannot receive the degree before the end of the fall quarter. If there were urgent reasons for doing so, I might be able to leave here in September and return to Ames in December for my final examination. I am married and have a son five years old.

Very truly yours,
Charles R. Henderson