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RANSOM LELAND ("LEE") BALDWIN V
1935–2007

A Biographical Memoir by
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Ransom L. Baldwin

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September 21, 1935–November 30, 2007

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Professor Ransom Leland ("Lee") Baldwin was born on September 21, 1935, in Meriden, Connecticut. Lee was the eldest of three children raised on the family dairy farm by Ransom and Edna Baldwin. He grew up doing farmwork and learning to milk cows, a background that led to his lifelong commitment to the dairy industry.

Lee's education started in Meriden where he attended Trumbull School, Jefferson Junior High School, and Meriden High School for his primary education, graduating in 1953. He attended the University of Connecticut where he earned a B.S. in animal industries and an M.S. in dairy nutrition. When his father was unable to milk due to an injury, Lee suspended his studies at the University of Connecticut for the good of the family but ultimately was able to continue. At Michigan State University he earned a Ph.D. in biochemistry and nutrition in 1963. He was a National Science Foundation fellow from 1957 to 1961.

Lee joined the faculty at the University of California at Davis in 1963, attaining the rank of professor in 1970. From 1992 to 2000 he served as Sesnon Professor of Animal Science. Lee retired in April 2001, following a 44-year career.

He met his wife, Mary Ellen, upon graduation from Meriden High School and they were married on June 1,

1957, following completion of his bachelor's degree from the University of Connecticut. Together they raised their three children Cheryl Choate, Randy Baldwin, and Robert Baldwin and a foster child, Angel Starr, in Davis, California. He had six grandchildren; Bobby and Andy Choate; Leland, Rebecca, and Sean Baldwin; and Nicholas Baldwin.

During his UC Davis career, Lee took several sabbaticals that helped to broaden his research, including trips to Philadelphia, Pennsylvania; Raleigh, North Carolina; Castle Hill, Australia; Palmerston North, New Zealand; and Henley-on-Thames, England.

During Lee's early career he focused on the mechanisms of animal production in the context of practical application. Lee always gave credit where due, and appreciated the efforts of several excellent mentors. He recounted his early years:

> There are three persons who had major impacts upon my early development as a scientist. Professor Roy S. Emery, major professor for my M.S. degree and co-mentor during my Ph.D.; [his] training encouraged me to develop as a quantitative scientist—"Do your arithmetic and take a course on differential equations." Professor W. A. Wood wondered in my interview with him as a prospective student why I used statistical techniques in my M.S. Thesis—"What was wrong with your data?"—and taught me biochemistry, biochemical methods and theology, and most importantly perhaps, to take students for what they are and help them develop. Woody's advice in this regard is the reason I have helped train so many successful Ph.D. students, who, in turn, have contributed so much to our research program over the years. Professor Mag Ronning was my mentor during my early years on the faculty of the University of California at Davis and became the best and closest friend I have ever had. His wisdom, intellectual and personal support was absolutely critical and essential to my development as a scientist. I loved the man. (Baldwin, 1995)

TEACHING ENDEAVORS AND IMPACTS

There is no doubt that Lee intertwined his research and teaching endeavors during his long career. His primary

undergraduate courses were in nutritional energetics and in lactational biology. Students routinely recognized that he was extremely knowledgeable, enthusiastic, and approachable, and that he taught critical-thinking skills. Lee used the biology of lactation to teach undergraduate students how to take knowledge they had gained from their coursework and experiences and to integrate that knowledge into the understanding of the biology of a lactating animal. Lee would often say that the class may be about lactation but that he was teaching you how to think.

He often involved undergraduates in research efforts, teaching them how to ask a question, how to develop answers to those questions, and how to use data to evaluate how well the question was asked and how well the experiment was designed. He taught students problem-solving skills and watched as students found excitement and satisfaction in realizing that they had the ability to learn on their own. He brought students to the realization that learning is not an act of memorizing facts; rather, knowledge is gained by asking questions and critically evaluating the answers. He was a passionate educator with an exceptional gift for challenging his students to integrate knowledge from different disciplines.

Lee's course in lactation was devised to impart an integrated understanding of biochemical, genetic, nutritional, physiological, and structural factors relating to mammary gland development, the initiation and maintenance of lactation, the composition of milk and limits to productivity. A strong emphasis was placed on using knowledge from basic mathematics, chemistry, and biology to solve problems in animal production. Lee's students include many prominent veterinarians, research scientists in universities and industry, nutrition consultants, and a wide range of agriculturists.

Lee Baldwin began teaching the principles of nutritional

energetics in a time of historic change. The course evolved from a classical approach based on the teachings of energy metabolism pioneer Max Kleiber, author of the seminal text *The Fire of Life* (Kleiber, 1961) to one focusing on nutritional energetics, which determined animal-level input: output relationships, to one that emphasized the specific biochemical and physiological bases for energy expenditures. Much of Lee's work was foundational to the 40-year development of integrated systems of research and application in animal nutrition. His approach has now been adopted in most courses in nutritional energetics across the world.

The historical context of Baldwin's research beginnings cannot be overemphasized, as the time that encompassed Lee's education and early career bracketed the discovery of the structure of the genetic material, the fruition of pathway biochemistry, the recognition that enzymes and hormones were intricately related to the control of nutrient use, the final development of the Net Energy System of animal nutrient use, and the end of the era of respiration calorimetry as the major methodology in nutritional energetics. Baldwin was well trained and well situated to move from classical studies and he incorporated all the new techniques of biochemistry, molecular biology, nutrition, and statistics to begin the era of basic research in a practical context.

Lee's goal in teaching nutritional energetics was to train students to integrate and apply quantitative techniques in problem solving. An example of his integration of research and teaching endeavors to further basic science approaches to practical problems was a paper published rather early in his career entitled: "Estimation of Theoretical Calorific Relationships as a Teaching Technique; a Review" (1968). In this easy-to-read and concise paper Lee took students through a quantitative description of the actual biological (biochemical) processes that made up the classical empirical

categories of the Net Energy System. What was the cost of digestion? What aggregated pathways were used to store glucose as glycogen or fat? What was the energetic cost of fat and protein synthesis? What is the biochemical efficiency of synthesis of milk of a given composition? This paper is one of the first to focus on the actual biochemical processes and control elements that make up the practical animal-level outcomes in growth and lactation. This publication also demonstrates Lee's early commitment to integrative biology and to training future generations of students.

RESEARCH AND GRADUATE EDUCATION PROGRAM

Lee Baldwin maintained an extremely productive research and graduate training program spanning five decades. From his earliest efforts as an assistant professor of animal sciences at UC Davis to his retirement as Sesnon professor (above rank) and member of the National Academy of Sciences (in 1993), Lee never lost sight of the importance of a rationally thought-out and followed research plan, integrated seamlessly with a similar graduate training program. Today the dozens of graduate students trained by Baldwin make up a significant core of productive animal scientists in education and industry around the world.

In the introduction to "Modeling Ruminant Digestion and Metabolism" (1995) he states that his

> research program is best characterized as one which couples experimental reduction and analysis with the use of mathematical modeling to achieve synthesis, integration and effective utilization of knowledge of underlying function in the solution of problems in ruminant animal production. Food-producing animals, particularly ruminants, play a key role in converting plant products humans cannot or do not choose to consume into desirable, high-quality human food…There is general agreement among most informed authors that products of animal agriculture will continue to contribute significantly to the world food supply. However, the key challenge of ascertaining how much animals should contribute has not been resolved. Resolution of

this issue requires quantitative consideration of the above statements, and additional issues to determine optimal balances and interactions between plant and animal agriculture in differing agricultural lands, climates and physical and societal circumstances in the world. A comprehensive model adequate for optimization of a human food production system is not available…Our inability to undertake quantitative evaluations of impacts of competing human nutrition strategies on human food availability is due in large part to the fact that current plant and animal production models are normally restricted to single species and have not been interfaced…This is a long-term goal that will require the availability of advanced dynamic, mechanistic models of ruminant digestion and metabolism.

Certainly in retrospect his research and graduate training program followed the philosophy laid out above. Starting from basic ruminant microbiology, a new field at the time, and moving to animal and tissue and pathway-level energetics, to tissue growth and development, to practical animal feeding strategies, Lee helped lead the way for a generation of scientists to ask basic research questions about the way animals use and store energy and ways to use this knowledge to improve food production.

The results of his studies of ruminal and tissue metabolism are the material upon which microbial and digestive and metabolic elements of all lactating cow-feeding systems worldwide are based, including the National Research Council, the Cornell Net Carbohydrate and Protein System, CPM Dairy, and the various systems in use in Europe and Australasia.

His research findings provided key data and concepts on mammary gland function, alone and with interacting tissues, such as adipose tissue, liver, and muscle. Whatever methods were germane to the key questions were utilized, including whole-animal energy balance experiments, intact and endocrinectomized animals, radiotracers, tissue slice and isolated cell incubations to study biochemical and metabolic control mechanisms and responses to endocrine, dietary, and physiological manipulations. A pioneering feature of Professor

Baldwin's research on tissue metabolic functions has been the use of experimental protocols that reveal kinetic properties of tissues and enable quantitative and time-dynamic evaluations of factors that determine patterns of nutrient utilization. Baldwin was one of the first to champion the combination of in vivo and in vitro experiments to extract the greatest possible knowledge and quantitative descriptions from every experiment. This research has had a major impact on our knowledge of basic metabolic processes involved in the initiation and maintenance of lactation and has provided considerable insight regarding interactions among diet, stage of lactation, and yields of milk and milk components.

Lee was one of the founding fathers of modeling in animal science, introducing process-based simulation modeling using differential equations. The specific focus of his research program was to integrate the key control elements of biology into a model of the whole animal. Starting with publications dating to the 1960s and continuing into the 21st century, he focused on the development of biochemical, mechanistic, dynamic, computer-assisted models of ruminal function and tissue metabolism, primarily in lactating cattle. This work led to the development of a computer model of rumen and tissue metabolism in the lactating cow, named "Molly" by Lee. In the 1980s the first working version of this model was named "Myrtle," after a calf on his father's dairy farm. A second version was named "Daisy," and in Lee's words:

> Over the 6 year period (1986-1992) during which DAISY reigned, many piecemeal changes were introduced and the flow of biological logic became disjointed, e.g. DAISY got old; after all, most cows are culled before they complete six lactation cycles. Therefore, the program was reorganized, corrected, and formatted to form MOLLY, named for the very docile, patient cow to which my father assigned the task of teaching me to milk by hand when I was 8 or 9 years old. Perhaps MOLLY will provide me and associates with a continuing opportunity to learn. (Baldwin, 1995, pp. 472-473)

The current lactating cow model is now much improved over the version published in Lee Baldwin's book and is very user friendly. The model clearly demonstrates that being dynamic and mechanistic offers several specific advantages over current feeding systems, which are largely empirical, factorial, and static. A specific advantage is that it accommodates effects of current feeding practices in practical use upon subsequent performance that can influence milk yields in full lactations, including resultant economic benefits. Another advantage is that it traces the metabolism of individual nutrients rather than aggregate entities such as metabolizable energy. Because different nutrients are used for different purposes at differing efficiencies, this model predicts effects of diets of greatly differing composition upon lactational performance in a superior fashion. Today Lee's model and, more importantly, his integrated approach continues to define ruminant food production in Europe, the United States, Australia, Canada, and New Zealand.

Lee's career was certainly strengthened by a number of sabbatical leaves. His first was with David Garfinkel, where he learned in-depth mathematical descriptions of biochemical equations, in his case of carbohydrate metabolism. He was highly impressed with and influenced by Garfinkel's work, which served as the philosophical foundation of his devotion to mathematical aspects of biology. He took a further sabbatical leave in Australia, with Professor John Black, to work on ruminal metabolism and the "beginnings" of what eventually became the "Molly" model. John Black had a great career in Australia bringing mathematical precision and logic to animal production, in pigs and in ruminants, for which he was later awarded the honor of Member of the Australian Order. Lee's last sabbatical was at the Hurley Research Center in England, working with John Thornley, Jim France, David Beever, and Maggie Gill to complete

the first published in-depth mathematical model of animal metabolism, published in a series of papers in the *Journal of Dairy Research*. That work is a foundational work of research in nutrient use in farm animals.

Professor Baldwin contributed to several important national and international committees on animal nutrition and agriculture that directly affected the economic and biological efficiency of animal production. All revisions of the National Research Council Nutrient Requirements of Dairy Cattle since the 1960s were directly conducted or significantly contributed to by Baldwin, or his students and direct colleagues. In addition, much of the research that was the foundation of the improvements in nutrient requirements came from his program or that of his students. Certainly the latest (at this time) revision (NRC, 2001) saw incorporated much of Baldwin's philosophy and much of his work in basic nutritional chemistry and animal physiology.

In later years Baldwin was called upon by many in agricultural education and planning, and his contributions (in addition to the NRC nutrient requirements documents) included Council for Agricultural Science and Technology (CAST) publications (P*reparing U.S. Agriculture for Global Climate Change* and *Contributions of Animal Agriculture to Global Human Food Demand*), the NRC Board on Agriculture's Committee on the Land University System, and the NRC-ILAR study *Guide for the Care and Use of Laboratory Animals*.

Professor Baldwin was one of the outstanding agricultural scientists of the past several decades. It is seldom that a scientist becomes nationally and internationally recognized for his research contributions; is recognized as an authority in several areas of basic research; and, in addition, demonstrates exceptional insight regarding animal production problems and approaches. Through penetrating and pioneering animal research and teaching activities, he has

created an entire generation of nutritional scientists, and altered the basic philosophy and application of agricultural research and education funding and conduct worldwide. In addition to the scientific and educational impact, it is a matter of historical record that application of his research and findings has led to a major increase in efficiency of animal production and an improvement in the nutritional health of millions of people.

PERSONAL NOTES

An anecdote related to one of the authors in 2007, upon the occasion of the American Dairy Science Association's 100th anniversary Pioneer Lectures, gives a good insight into Lee Baldwin's approach. While Lee was completing his doctoral degree with Roy Emery at Michigan State University, a young scientist by the name of H. Allen Tucker was interviewing for a position. Tucker indeed secured the position and went on to international recognition in the area of lactation biology. At the time, Tucker was studying how these newly discovered compounds RNA and DNA accumulated during the growth of the mammary gland. For his own work Lee was measuring microbial DNA in studies of ruminant microbiology. As related by Lee 50 years later, after Tucker's talk, he thought to himself: "I'm doing this all wrong!" and proceeded to go on at UC Davis to (correctly) quantify microbial and mammary growth through measuring accumulation of RNA and DNA. Many important discoveries and applications came from that chance meeting.

As a boy he participated in the St. Andrews Boy's Choir, and was an interested student. He was starting center and linebacker on his high school football team. Later, Lee had a voracious appetite for science fiction and was a dedicated 49ers football fan.

Later, a younger colleague at UC Davis recounted his

first months there. He had met and worked with Lee for a while and they were becoming friends. However, during a student's thesis defense, there was a serious scientific disagreement between them, and the young faculty member thought, "Now I've done it. I've made him mad and he'll make my life hell." Yet Lee had no problem whatsoever with a scientific disagreement and continued to befriend his colleague for the rest of his life. "Once he was your friend, he was your friend for life."

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