How we got to now in food animal agriculture: animal science innovations that made the modern world in the West

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Transl. Anim. Sci. 2018.2:S1–S8
doi: 10.1093/tas/txy067

HOW WE GOT TO NOW—THE PRIVILEGE OF WATCHING IT HAPPEN

My career in animal science began as a young boy on a diversified family farm in northeastern Utah. I recall a story I once heard about a man who grew up in a family atmosphere similar to mine (Dunn, 1974). This man’s father worked off the farm, and because he saw the need for his boys to learn the principle of work, his father put the boys to work on a farm in his absence. Over the course of time, one of the neighbors noticed some mistakes the boys were making. The neighbor went into his father’s business to tell him the things he thought the boys were doing wrong. The father listened to the neighbor carefully and then said, “Jim, you don’t understand. You see, I’m not raising cows, I’m raising boys.” I was also fortunate to have a father who saw the importance of not just raising cows but raising boys. These early-in-life experiences introduced me to many of the fundamental principles of animal production that I have had the opportunity to explore at a deeper level since then.

HOW WE GOT TO NOW

A few months ago a colleague directed me to an interesting audiobook by Steven Johnson titled How We Got to Now—Six Innovations That Made the Modern World. Steven Johnson is an author who writes about science and technology. In How We Got to Now, Johnson explores the history of innovations over the centuries and how six particular innovations have affected our lives in today’s modern world. As I listened to the audiobook, I was fascinated. It caused me not only to consider the six world-changing innovations described by Johnson—namely, glass, cold, sound, clean, time, and light—but also changes in our discipline of Animal Science, specifically, those I have observed during my career and since the science of animal production began. I thought exploring the evolution of a few of these animal science innovations would be an interesting theme for this presentation.

Johnson notes several key characteristics inherent to discovery and innovations. I suggest these characteristics apply equally to animal science, as well as other disciplines. Table 1 lists some of the characteristics Johnson describes in this audiobook.

TRAJECTORY OF ANIMAL AGRICULTURE OUTPUT

A major innovation in animal agriculture over the past century is the tremendous increase and continued upward trajectory of protein production from animal products. Numerous changes in output and production efficiency have occurred in crop and animal production systems in modern times. Advances, in large measure, trace back to innovations and discoveries resulting from adoption and modification of production techniques and technologies. Several publications discuss the output advances that have occurred in food animal production, resulting from use of technologies (Raun}
and Preston, 2002; Wileman et al., 2009; Maxwell et al., 2015). In an on-line article by Maria Trimarchi (Trimarchi, 2014), which discusses the steps that American agriculture has seen, she states:

“In the 1930s one American farmer produced enough agricultural product to feed a total of four people; a family farm was literally meant to feed a family [source: Kirschenmann, 2001]. Fast forward 40 years, and that number increases from four people to 73. Fast forward through 80 years of agricultural and bioscience innovation, and in the 2010s, one farmer produces enough food to feed 155 people [sources: USDA, 2014; Sullivan, 2014].”

Below are charts to illustrate some of the dramatic increases in agricultural productivity over time. One commodity that illustrates this increase well, and is relatively universal in American agriculture, is corn. Figure 1 visually portrays the 8-fold increase in average U.S. corn yield that has occurred since the 1930s. Many factors contribute to this increase, including, genetic selection (specifically hybridization), disease and pest management practices, fertilization, water management, and much more. Troyer (1999) presents a historical narrative of corn development with specific reference to hybrid corn. Drawing on some of Johnson’s stated key characteristics inherent to discovery and innovations, factors such as a systems approach, information spillover, collaboration, along with information flow and communication undoubtedly played pivotal roles in the resulting increase in corn yield in this example.

Similar increases in output are illustrated in Figures 2 and 3 for beef and dairy productivity. Figure 2 illustrates improvements in biological efficiency across the 42-year period from 1970 to 2012, by expressing the number of beef cows per 100 people contrasted with the pounds of beef produced per cow. Fewer cows, yet greater production. In the accompanying article to this figure (Lusk, 2013), the author, J. L. Lusk noted: “It would be a mistake to focus solely on increases in agricultural
productivity without asking how productivity growth was achieved. The key contributor to productivity growth has been investments in research and development (Alston et al., 1995).” These investments have facilitated additional characteristics inherent in innovation and discovery previously noted by Johnson. For example, team dynamics and synergies play critical roles within the land-grant university system past, present, and future.

Like the increase in production efficiency noted for beef cattle, Figure 3 depicts data from the USDA Economic Research Service to illustrate the increase in milk production during the 34-year period from 1980 to 2014. This milk production increase is compared with the corresponding decrease in number of milk cows. Even though the number of milk cows has been rather stable since the late 1990s, the total milk production continues to climb. The production curves shown in both Figures 2 and 3 clearly demonstrate the upward trajectory of food animal output. Evidence that the combined innovation by researchers, producers, and industry continues to succeed in the quest to produce animal proteins for an ever-increasing population.

**HOW WE GOT TO NOW: KEY INNOVATIONS THAT MADE MODERN ANIMAL PRODUCTION**

Numerous ideas, publications, and philosophies have contributed to the increases in production and production efficiencies described in the previous section of this paper. I suppose if any other person in the Western Section were preparing this paper and presentation, there would be many different perspectives of “how we got to now.” However, since I am the one doing so at this meeting, this gives me license to focus on some of the innovations I have seen during my career.

**A STRAW POLL SURVEY**

In preparation for this presentation, I conducted a “straw poll” of 11 past WSASAS Distinguished Service Awardees and nine current WSASAS officers. I also sampled 14 other miscellaneous thought leaders who are WSASAS members. The objective of my brief survey was to ascertain their perspective of the top innovations that have influenced our current food animal production practices in the west.

This was by no means a wide-ranging random study and likely highly biased by the sample used. However, I was seeking an honest opinion from those I felt had a good perspective of the following question posed in the survey:

**Question:** In your opinion, what are the six most innovative, profound, game-changing technologies/practices that have caused the greatest impact on food animal agriculture in the past 100 years? You may define impact in whatever manner you care to. Please focus your responses on food animal production in the Western United States (i.e., Western Section of ASAS).

The results of this survey are shown in Table 2.

Respondents were asked to select their top 6 from a list of 14 various technologies or practices; plus, they could add their own suggested technology to the list. They were asked to respond based on their opinion of technologies or practices that have caused the greatest impact on food animal agriculture in the past 100 yr with particular emphasis on the Western United States. Table 2 shows the results of this survey and lists the number of times each was ranked 1–6 and a weighted average score. There
were 14 respondents, a 41.2% response rate. Even though responses from each person were limited to their top six items, the eight items with the highest responses are included.

An entire paper could easily be devoted to describing each of these eight innovations. However, in the interest of time and space, I will only expand on the two I have been fortunate to have direct involvement in. I will attempt to tie the development of these two innovations into the characteristics noted by Steven Johnson.

**SUPPLEMENTATION STRATEGIES FOR GRAZING LIVESTOCK**

When I started my PhD program at the University of Nebraska with Dr. Don Clanton, I learned about the work he did for his own PhD program at Utah State University in the mid-1950s. Don worked with two of the early range livestock nutrition legends, Dr. Lorin E. Harris, an animal scientist and Dr. C. Wayne Cook, a range scientist, then on the faculty at Utah State. When I arrived in Nebraska for graduate school in 1982, Don told me about his PhD thesis project in southeastern Nevada and southwestern Utah and how it came about. This background stimulated my interest in range production systems, which I have participated in at various levels during my career.

Dr. Clanton explained to me that in the late 1940s and early 1950s, the Atomic Energy Commission issued a call for proposals to evaluate the nutritional status of the rangelands in that region. The grant to study the range nutrition of cattle was awarded to the University of Nevada, and a grant to study range nutrition in sheep was awarded to Utah State under the direction of Dr. Harris.

*Clanton et al.* (1959) reported the results of this work in the Journal of Animal Science. They concluded from these and other studies by Harris and Cook (*Harris et al.*, 1952; *Harris et al.*, 1956) “that (1) sheep are very selective in choosing their diet, (2) vegetative type, stage of growth, and site affect the nutritive content of the range forage, (3) most of the desert-type winter ranges provide inadequate amounts of phosphorus, protein and energy for optimum production in range ewes.” This was some of the early research that leads to the subdiscipline of range livestock nutrition, an area of study which has had tremendous impact on livestock and range production in the Western United States.

*Harris et al.* (1952) outlined four phases of range nutrition research, which are necessary before recommendations are made to stockmen on feeding supplements and management practices. These phases include 1) factors that affect the chemical composition of a given range species, 2) the botanical and nutritive composition of the sheep’s diet, 3) supplementary feeding trials on a detailed experimental basis, and 4) supplementary feeding trials on a practical basis using some of the most valuable supplements in various combinations, amounts, and seasons.

In terms of Steven Johnson’s characteristics of innovation, the work reported by Clanton et al.

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**Table 2. Straw poll survey of 34 Western Section ASAS members (11 previous WSASAS distinguished service awardees, 9 current WSASAS officers, and 14 additional WSASAS thought leaders)**

| Overall rank | Innovation | 1* | 2 | 3 | 4 | 5 | 6 | Average score† | Number of respondents selecting item in top six |
|--------------|------------|----|---|---|---|---|---|----------------|---------------------------------------------|
| 1            | Crossbreeding and selection within breeds | 7  | 0 | 4 | 1 | 0 | 2 | 2.50           | 14                                          |
| 2            | Nutritional interactions with reproductive performance | 1  | 4 | 3 | 1 | 2 | 0 | 2.91           | 11                                          |
| 3            | Animal vaccine development | 3  | 1 | 0 | 4 | 2 | 0 | 3.10           | 10                                          |
| 4            | Frozen semen | 1  | 3 | 1 | 1 | 3 | 0 | 3.22           | 9                                           |
| 5            | Genetic prediction models (EPDs, etc.) | 0  | 3 | 5 | 2 | 1 | 1 | 3.33           | 12                                          |
| 6            | Artificial insemination and estrous cycle manipulation | 0  | 5 | 2 | 4 | 0 | 3 | 3.57           | 14                                          |
| 7            | Genomics and DNA sequencing | 2  | 1 | 0 | 0 | 3 | 1 | 3.57           | 7                                           |
| 8            | Supplementation strategies for grazing livestock | 1  | 1 | 1 | 0 | 0 | 2 | 3.60           | 5                                           |

There were 14 responses (41.2%).

*Number of times the item was selected in each ranking.

†Lower average score = more important.
(1959) and by Harris et al. (1952) might well be classified as “information spillover” resulting from studying the impacts of nuclear testing on livestock and elucidating the benefits of protein and energy supplementation on winter range.

Furthermore, this area of scientific investigation benefitted by another of Johnson’s innovation characteristics he called “information flow and communication.” A key example of this information flow is illustrated by a series of conferences that have been organized under the leadership of a USDA regional research coordinating committee previously known as WERA 110, later changed to W 1012 and currently designated as the W 2012 Multistate Research Project.

A paragraph from the Forward of the Proceedings of the 4th Grazing Livestock Nutrition Conference held in Estes Park, Colorado in July 2010 provides insight into the history and impact of this conference series that began in 1987.

“Welcome to the Fourth Grazing Livestock Nutrition Conference. The first call-to-order occurred in July 1987 at Jackson Hole, Wyoming. That meeting was dedicated to Drs. Lorin Harris and C. Wayne Cook who inspired the science of Range Livestock Nutrition in the Western United States. Therefore, we would like to dedicate this fourth conference to members of the original planning committee, Dr. D. C. Clanton, Professor Emeritus, University of Nebraska, Dr. J. E. Wallace, Professor Emeritus, New Mexico State University, and Dr. F. Hinds, Professor Emeritus, University of Wyoming. Much of the discussions at this conference are outcomes of their research. We are indebted to them for their foresight and example.”

These conferences are typically held as a preconference or postconference when the national American Society of Animal Science meetings are held in the Western Section. The most recent conference, the 5th Grazing Livestock Nutrition Conference was held in 2016 at Park City, Utah as a preconference to the national ASAS meetings held the following week in Salt Lake City, Utah.

Numerous symposia, conferences, and research publications (DelCurto et al., 2000) related to the general topic of range livestock nutrition have occurred in the Western Section of ASAS since the work in the 1950s by Clanton and others. The practice of supplementing grazing livestock with various levels of protein, energy, vitamins, and minerals is a mainstay of most production systems. It has also been the stimulus of a vast nutrition industry that provides products, consultations, and analysis services to the livestock sector. In my estimation, this is one of the innovations that has “brought us to now” in range livestock production in the west.

**ARTIFICIAL INSEMINATION AND ESTROUS CYCLE MANIPULATION**

When looking at any bull semen catalog today, you will see diagrams of systems that facilitate fixed-time AI. This innovation is a key step that has brought us to now. This now makes it possible to have more than half of the cowherd pregnant to AI on the first day of the breeding season. How did we get to now with this technology?

Understanding the full story of how we got to now with TAI could start long ago, since reproduction of farm animals has been under study for centuries. Due to limitations of scope and time in this paper and presentation, I will begin with a reference to a seminal (pun intended) review paper presented at the Diamond Jubilee 75th year anniversary of the American Society of Animal Science in 1983 at Pullman, WA by Dziuk and Bellows (1983). In this 1983 review, the authors make the following prognostication:

“Use of AI will potentially increase in the future. This increase will occur because of attaining successful treatments to control ovulation and improved semen processing techniques that will result in higher conception rates than is obtained through use of natural service.”

Lauderdale (2010) presented an extensive review of protocols for breeding management at the Applied Reproductive Strategies in Beef Cattle (ARSBc) Symposium in San Antonio in 2010. This comprehensive paper details development in understanding estrus, the estrous cycle, follicle dynamics, hormonal factors, and strategies to manage the estrous cycle. Lauderdale (2010) outlines the progression in the use of exogenous progestins, prostaglandins, and gonadotropin-releasing hormone to control ovulation. All of these are important steps in how we got to now relative to successful TAI.

**Roy Wallace, the Select Sires Think Tank and Roy’s Wish**

A key person who in many ways guided progress toward dependable TAI was Roy Wallace. Roy joined the Select Sires staff in 1969 as a beef sire analyst and later became the vice president of beef programs. Roy had a wish—a vision really—to make artificial insemination practical and affordable enough for it to be adopted widely in commercial beef herds. To this end, for over 12 yr, Select Sires, under Roy’s leadership, hosted an annual “Think Tank” beginning in the mid-1990s. This forum brought together those in universities, industry, and bull studs who were working to understand
and develop systems to manage ovulation for successful TAI. The Select Sires Think Tank was the forerunner to the Beef Reproduction Task Force (BRTF). The review article by Lauderdale (2010) presents an excellent history of the BRTF and ARSBC.

**Development of OvSynch and CO-Synch**

In a previous section of this paper, I referred to “the privilege of watching it happen” as it related to several of the key innovations in today’s modern world of animal agriculture. A major step toward the reality of controlling ovulation in a manner suitable to attain high TAI rates occurred first in the dairy cow when a system of hormone injections led to a protocol termed “OvSynch” published by Pursley et al. (1995). The OvSynch protocol evolved as numerous researchers elucidated a more clear understanding in the biology, physiology, and endocrine system of the cow as detailed by Lauderdale (2010). These and other researchers assembled a sequence of hormone injections designed to move beyond just synchronizing behavioral estrus, an indirect indicator of ovulation, to synchronizing ovulation. The OvSynch protocol was a major step toward effectively controlling the development and resulting ovulation of viable oocytes. OvSynch resulted in ovulation at a predictable time across all stages of the estrous cycle at time of protocol initiation.

A major challenge with the widespread use of the OvSynch protocol in beef cows was the necessity of working cows through a chute four times in a 10-d period. In dairy cows, this was not as big of a challenge since dairy cows are managed in confinement where proximity to working facilities or feeding manure lockups is easily at hand. Therefore, the OvSynch protocol quickly became the norm for managing breeding in dairies.

In most commercial beef operations, particularly those in extensive range operations, gathering and processing cows through a chute were more difficult than in dairy applications. It was during this era that several groups across the country were researching methods to predictably develop satisfactory TIA programs in beef cows as well as in dairies.

I was fortunate during that era to work alongside Dr. Tom Geary while we were both on the Animal Science faculty at Colorado State University. When the buzz about the OvSynch success in dairy cows was occurring in both scientific and production circles, I remember sitting with Tom in a conference room at CSU and asking ourselves the question “Is there a way to modify the OvSynch protocol to be more practical in a beef cow setting?” That idea grew into a modification of OvSynch, whereby TAI was done at the same pass through the chute, as when the second GnRH injection was administered rather than waiting 24 h to inseminate as is done with OvSynch.

From that brainstorming session, we designed a multilocation study to evaluate this modified protocol. After we had conducted the studies, we presented our early results in a producer meeting in Yuma, Colorado. As Tom and I were driving home from this meeting, we discussed what we might name this protocol. During this era, there were a number of ovulation synchronization protocols under evaluation with names given to differentiate and describe each protocol. As we brainstormed about names, we settled on CO-Synch. This name seemed appropriate since it was developed in Colorado and the accepted two-letter abbreviation for Colorado is “CO,” and because in this protocol, insemination and the second GnRH injection in the protocol cow “co”-incide with each other. This seemed to be a suitable name. The name CO-Synch caught on and was accepted well by the industry then and now. We published our work with CO-Synch in 1998 (Geary and Whittier, 1998).

**Characterization of Follicle Waves and Development of CIDR Devices**

Two important steps took place in this progression of how we got to now with TAI. The first was ultrasonography improvement, so real-time, non-invasive characterization of follicular dynamics occurred. A second key step to improve response and success of TAI systems came when a practical method for intravaginal administration of progestins became readily available. In 1997, FDA CVM approved and U.S. marketing by Pfizer began, for the Eazi-Breed CIDR controlled intravaginal drug release (CIDR) coupled with PGF2α, for estrus synchronization of beef cattle and dairy heifers (Anonymous, 1997). This technology further accelerated refinement and adoption of successful systems for TAI in commercial beef cattle operations by managing both the follicles and the corpus luteum effectively to better pinpoint the time of ovulation when viable sperm cells were present in the reproductive tract.

Lucy et al. (2001) published results of an extensive field trial investigating estrus synchronization using the intravaginal progesterone-releasing insert
containing 1.38-g progesterone (CIDR) inserted for 7 d plus 25-mg PGF2α on day six. The availability of CIDRs was a major step in refining and targeting ovulation protocols specific for heifers, cows, and other subpopulations of beef and dairy animals.

MORE INNOVATIONS NEEDED AND MORE INNOVATIONS TO COME

The Food and Agriculture Organization of the United Nations (Alexandratos and Bruinsma, 2012) projected the world population to grow by over a third, or 2.3 billion people, between 2009 and 2050. Furthermore, the February 2018 issue of National Geographic magazine (Goldberg, 2018) listed the following projections of population dynamics in the coming decades.

- 66% of the world’s population will live in an urban area by 2050.
- 41 cities will have more than 10 million inhabitants in 2030, up from 31 in 2016.
- 10 million people will be added to the population of Delhi, India by 2030, for a total of more than 36 million.

This growth will result in marked increases in consumption of animal-based protein and total calories. It has been estimated that food production must double by 2025 to meet this demand (United Nations, 2009). Much has been written and discussed about how this increase in food production will occur since this prediction was made.

Galyean et al. (2011) addressed the future of beef production in North America. Their review included industry structure and demographics, feeding and management practices, and external pressures such as animal welfare and food safety issues. They concluded:

“Beef production as currently practiced in North America, especially in the United States and Canada, is highly efficient. Combined with this efficiency, efforts to decrease the environmental footprint of beef production and to guarantee the highest possible standards of animal welfare and food safety will ensure the long-term future of the North American beef industry.”

I generally consider myself an optimist rather than a pessimist or fatalist. I am confident in the ingenuity of mankind that has brought us to now. I believe this advancement and ingenuity will continue to develop new and better innovations to meet this growing demand for food.

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