The USDA Animal Improvement Programs Laboratory: A century old and just getting started

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AIPL Research Report HIST1 (10-08)

Data || Progeny testing || Genetics || Evaluations || Identification || Computing || International selection || Genomics || Conclusion || AIPL history on the web || References & additional resources || Acknowledgments

In the beginning, breeders had no data.

Data

In 1908, USDA's Bureau of Animal Industry hired Helmer Rabild (Figure 1) to organize cow testing associations nationally. Those associations led to the national Dairy Herd Improvement Association (**DHIA**). Rabild had organized the first cow testing association in the United States in 1905 for Michigan's State Dairy and Food Department (Michigan Department of Agriculture). Breed associations had conducted some milk recording prior to 1905, and the Illinois Agricultural Experiment station had a small group of producers that collected weekly butterfat samples. However, the hiring of a milk tester by local farmers to travel from farm to farm to test butterfat samples and to collect data for use in herd management was the central principle that made DHIA successful.

Figure 1. Helmer Rabild, organizer of the first U.S. DHIA.

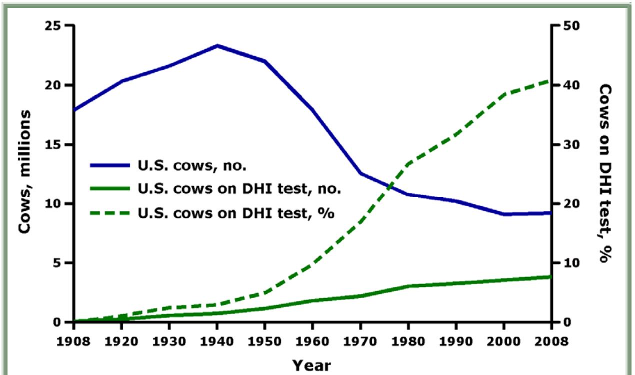

Figure 2. A century of growth in Dairy Herd Improvement (**DHI**) testing.

Rabild learned about milk recording and cooperative bull associations in Denmark and graduated from the Agricultural College of Denmark before moving to Michigan in 1898. His leadership and guidance carried the idea of organized production testing to all the States. Leadership of the state cow testing associations switched to Federal Extension workers in 1914. With their help, the national database grew steadily. Percentages of cows with official records increased from 0.02% in 1908 to 40.8% in 2008 (Figure 2).

In 1927, cow testing associations were renamed DHIAs to reflect the vast amount of herd management information that was being collected. The USDA Laboratory known as the Division of Dairy Herd Improvement Investigations was renamed the Animal Improvement Programs Laboratory (**AIPL**) in 1972.

Progeny testing

The two ideas of data recording and progeny testing were closely connected, and Rabild's early work helped introduce and advance both. From 1906 to 1908, the first three bull associations were formed in Michigan, also following examples from previous cooperatives organized in Denmark. The National Association of Animal Breeders can be traced back to those associations formed a century ago. Bull associations shared bulls using natural service during the three decades from 1908 until Enos Perry introduced the technology of artificial insemination (**AI**) from Denmark in 1937. Much of the original research on AI was done in Russia around 1900 by E.I. Ivanov.

Many of today's AI companies were formed as natural-service cooperatives prior to 1927 by signing USDA forms BDIM-676 ("Membership Agreement for Cooperative Dairy Bull Association") and BDIM-677 ("Suggested

Constitution and By-Laws for Cooperative Dairy Bull Association”). Bull associations also kept their financial records in books printed by the Bureau of Dairy Industry. Film strips showing how to manage bulls and how to organize bull associations were distributed by USDA in the early 1930s. By 1927, more than 250 local bull associations that owned 1,117 bulls and had 6,057 members were reported to USDA (Figure 3). Number of cows bred by bull associations reached a high of 43,251 per year in 1942 and then declined as AI took over.

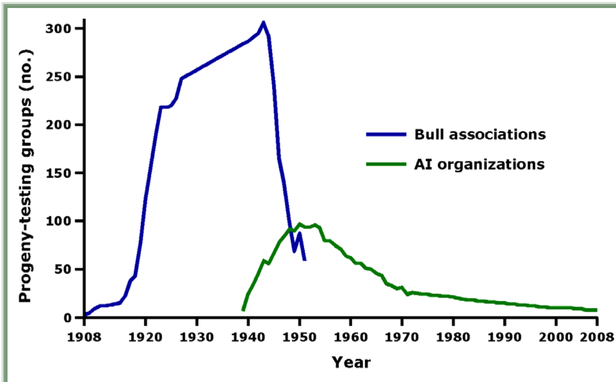

Figure 3. Numbers of U.S. progeny-testing groups.

After 1938, the use of AI increased rapidly, perhaps because organizations and leadership were already in place. The USDA promoted AI and provided yearly updates on its national growth (Figure 3). By 1955, Wisconsin and Minnesota each had more than 20 artificial breeding associations, and Indiana, California, and Virginia each had more than 10. The original organization codes were sequential within State. For example, the code for Central Ohio was 31-01 (now part of Select Sires, code 7), Tri-State was 35-05 (now Accelerated, code 14), and American Breeders Service was 35-75 (now ABS Global, code 29). Eventually, 48 AI cooperatives including Badger (code 35-02) merged into Genex (now code 1). A private breeding company also began 100 years ago. In 1908, Carnation farms began to buy and sell bulls for breeding, eventually becoming Landmark Genetics, now Alta (code 11).

In 1918, USDA began leasing many of its young bulls to other farmers to develop proven sires. A total of 1,200 bulls were leased over the next 40 years. In 1927, J.C. McDowell stated: “Eventually the time will come when bulls will be selected on the records of descendants as well as on those of ancestors. When that time comes dairying will have completely eliminated another piece of guesswork.” In 1958, 28 AI organizations cooperated to compare their best bulls by mating them to cows in 19 USDA experimental herds.

Genetics

A pioneer in developing applications of population genetics for improving animal breeding, Jay Lush wrote in 1956:

“In 1906, enthusiasm about the practical results to be had from applying the recently rediscovered Mendel's Law was running high among a few of those who had heard of it … But the number of genes turned out to be so large and their ways of interacting with each other so unpredictable and infinitely numerous that most of the early hopes of quick applications of simple Mendelism to practical plant and animal breeding grew dim … The better informed breeders of dairy cattle in 1906 were already well informed about Darwin's views and Galton's attempts to quantify the observed facts of heredity. The Mendelian discoveries did little at first to change their operations but did much to take the mystery out of many hitherto puzzling things … Also, it put a more solid floor under the reasonable use of progeny tests and of pedigrees.”

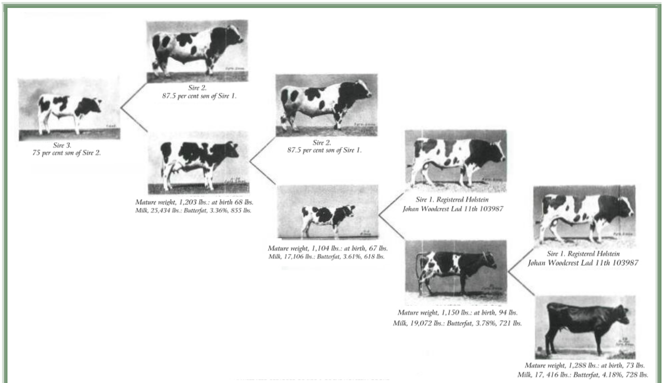

Figure 4. Pedigree of sire 3 of the Holstein group for the 1912 USDA inbreeding experiment.

In 1912, USDA's Bureau of Animal Industry began an inbreeding experiment within Holsteins and Guernseys. The original breeding, pedigree, and production records from 8 generations of mating sires to their daughters and dams to their sons are still available at AIPL (Figure 4). In 1915, Sewall Wright was hired to develop mathematical tools for genetic analysis. His 1922 coefficients of inbreeding and relationship were used widely across biological studies and are the foundation of today’s animal-model genetic evaluations.

Evaluations

As early as 1915, some bull associations calculated daughter-dam differences for their own bulls. The earliest example found in AIPL files is from a bull association in New Windsor, MD. That evaluation included only 2 to 7 daughter-dam pairs for 3 sires.

In 1926, USDA calculated sire evaluations for 23 bulls and sent those results directly to each bull's owner. Records of each daughter and dam, averages of their milk and fat yields, and the daughter-dam differences were handwritten on form BDM 67 and mailed to a bull association in Grove City, PA, in April 1926. Owner W.A. Richardson replied that Maple Crest Dekol Pontiac Boy had been sold to the butcher after 6 years of service in the bull association and had sired about 100 daughters. The daughter-dam difference was the statistical method used by USDA for the next 35 years.

Sire evaluations began to be computed with a herdmate comparison in 1962 so that management differences could be considered. The modified contemporary comparison was introduced in 1974 to account for genetic trend better. The current animal model was implemented in 1989 and uses the relationships among all cows and bulls to produce more accurate evaluations.

Evaluations and production records were typed instead of handwritten on form BDM 67 after 1927. By 1937, sufficient bulls had daughter records to publish the sire evaluations in a book each year for wider distribution. Books were printed for nearly 40 years, but after 1975, distribution was paperless via computer tapes. After 1997, distribution was purely electronic via the internet. Until computers arrived, much of AIPL's budget was for data entry, data management, and printing the forms used to collect data from each farm. Computer technology has allowed AIPL get much more done per person and to focus more of our resources on science (Table 1).

Table 1. AIPL staffing and budget.

Year	Scientists and postdoctoral researchers	Total employees	Budget (× $1,000)
1946	0	100	
1951	0	70	300
1963	1	21	266
1978	5	20	1,180
1989	5	19	1,029
1991	6	20	1,021
1996	6	15	1,019
2000	5	18	1,575
2004	6	21	2,081
2008	4	16	2,070

Identification

Breed associations had assigned registration numbers as early as 1870, but most cows were grades and identified by eartag numbers that were not unique. In 1936, AIPL recognized the importance of national identification (**ID**) by introducing unique metal eartags that began with a State code such as 35 for WI and then 4 numbers within State such as 35-0001. After the State used its first 9999 tags, the next series began with 35A0001. After the State used its tags up to 35Z9999, the next series began at 35AA0001 and continued to 35ZZ9999. All tags were manufactured by William Cooper and Nephew, Chicago. Research leader Frank Kendrick (Figure 5) recommended in 1938 that "all animals in a herd, regardless of age, should be eartagged. The most important part of identifying animals with eartags is the record of that identification, including the parentage of each animal."

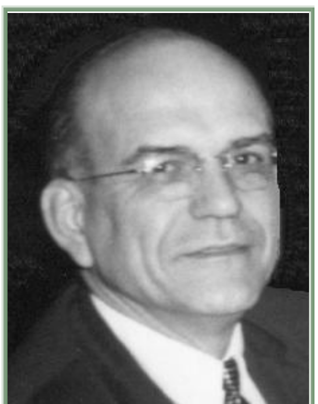

Figure 5. Frank Kendrick established a USDA computing center for dairy cattle evaluations in Washington, DC.

In 1955, AIPL, the Animal Plant and Health Inspection Service (**APHIS**), and the National Association of Animal Breeders (**NAAB**) agreed to a new eartag series to replace the separate DHI and disease number series used earlier. A third character was added to make all eartag numbers the same length in each State (e.g., 35AAA0001) as recommended by the American Dairy Science Association. Kendrick stated in a 1955 letter to APHIS: "In practice we find that the disease eartag numbers are duplicated between states and within states … Only one tag for an animal is important to many dairymen … Another advantage could develop if in the future you wished to keep a mechanized record system which would enable you to quickly locate the owner (at time of test) of any animal in the country."

In 1998, a new American ID series was introduced to replace the separate eartag and registration number series. American ID includes a two-character breed code, a three-character country code of USA, and individual ID up to 12 bytes (e.g., HOUSA000050000000). This structure allows animals to be marketed with the same unique ID around the world instead of being assigned a new ID in each country. Number blocks were assigned by NAAB, either consecutively with no check digit or nonconsecutively with a check digit to allow instant detection of 90% of keypunch mistakes. Organizations must remember to use only numbers within the blocks they are assigned.

In 2006, electronic ID numbers were accepted by AIPL. Those are all numeric with 840 instead of USA and use ID numbers greater than 003000000000.

Computing

Timely delivery of evaluations on schedule is a high priority in the breeding industry. Following World War II, the number of records grew quickly, but the number of clerical staff at AIPL dropped from 93 in 1946 to 57 in 1951, which resulted in a 2-year delay from the time records were received until sires were evaluated. The 1959 transition from punched-card processing to electronic computing (Figure 6) was partially financed by a $150,000 grant from J. Rockefeller Prentice, the owner of American Breeders Service.

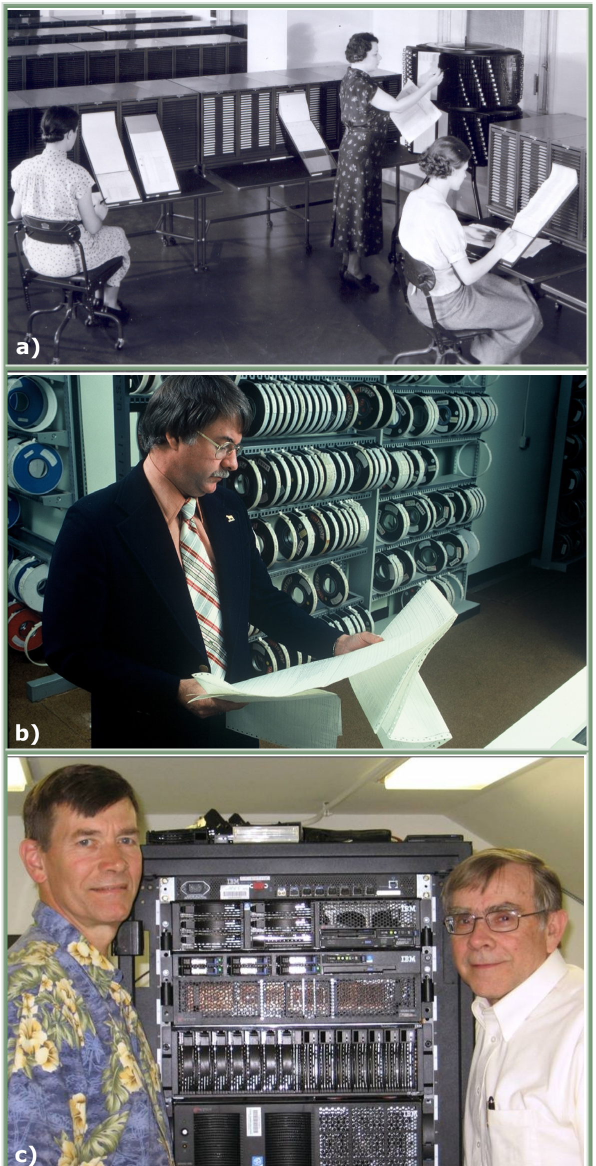

Figure 6. Data processing in **a)** 1936, **b)** the late 1970s (Frank Dickinson), and **c)** 1995 (Leigh Walton and Duane Norman).

As of August 2008, AIPL has delivered 95 national genetic evaluations on the scheduled dates. The last release date missed was in October 1974. Two slight exceptions were in 1993 when a redesign of all edit programs resulted in a 2-day delay in the delivery of cow evaluations (but bull evaluations were on time) and in February 2002 when bull evaluations were distributed 1 day late because of an evaluation recall and recalculation by the International Bull Evaluation Service (**Interbull**) in Sweden. Since 1998, AIPL has received three national awards for increasing computing efficiency.

International selection

Since the start of the dairy genetics program in 1908, USDA has been interested in foreign improvement programs. In 1928 and 1929, USDA's DHI Letters included detailed progress reports on milk recording in Germany, England, Finland, and Australia. Economic research by Robert Miller in 1977 questioned the dual-purpose breeding programs for dairy and beef traits in Europe as compared with specialized dairy selection in North America. During the next 20 to 30 years, the percentage of North American genes in foreign populations rose rapidly as breeders in many nations almost completely replaced local genes with imported genes.

From 1976 to 1995, genetic evaluations for Mexican Holsteins were computed by AIPL. From 1993 to 1996, rankings of all Canadian and U.S. bulls were distributed together in a combined file. This joint North American evaluation using conversion equations led directly to Interbull's 1995 multitrait across-country evaluation system now used to rank bulls worldwide.

Genomics

A century after USDA began a national database of phenotypes, USDA began an international database of genotypes. In 1991, North American AI companies provided semen samples from 1,068 bulls in 8 sire families to begin a genomic scan using 174 microsatellite markers. That cooperative project with researchers from the University of Illinois, Israel, and AIPL attempted to discover if any major genes exist. In 1995, USDA began a new Gene Evaluation and Mapping Laboratory, later renamed the Bovine Functional Genomics Laboratory (BFGL). The research project was expanded to 367 markers, 1,415 bulls, and 10 families. In 1999, North American AI companies began routinely sending semen samples for all progeny-test bulls to BFGL.

In 2007, BFGL, Illumina, and other research partners developed a chip (Figure 7) to genotype more than 50,000 single nucleotide polymorphism (SNP) markers. Already during the first year, more than 10,000 animals have been genotyped with that chip. A low-density chip is now being developed to provide information from the most significant markers at less cost. Tools for DNA genotyping and sequencing are rapidly becoming much more affordable. In 2008, AIPL began sending genomic predictions to AI companies, breed associations, and breeders for use in selection. Programming is mostly complete to replace the traditional evaluations with genomic evaluations in January 2009.

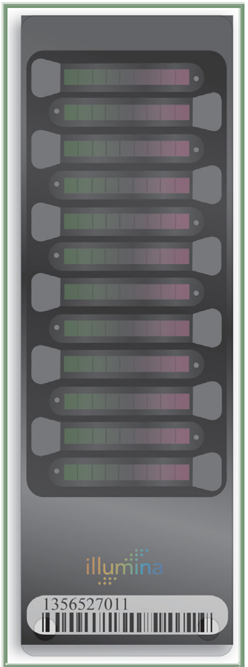

Figure 7. Illumina Bovine SNP50 BeadChip. ©2008, Illumina Inc. All rights reserved.

Conclusion

Much genetic improvement (Figure 8) has occurred during AIPL's first 100 years due to steady advances in data collection, evaluation, computation, and understanding of genetic principles. Much of the credit for that success goes to the Extension Service that promoted and managed data collection in each State, the breed associations and private organizations that interacted directly with breeders, and the dairy producers who participated over the 100 years. Their motives were primarily to gather information to improve management and economic returns, which is still true today. Data recording is considered to be a mark of sound management and is expected to continue to flourish and to expand. Use of those data for genetic improvement is a byproduct at relatively little additional cost. Public funding for research allowed AIPL to discover and to implement many new tools for use by all breeders nationally and internationally.

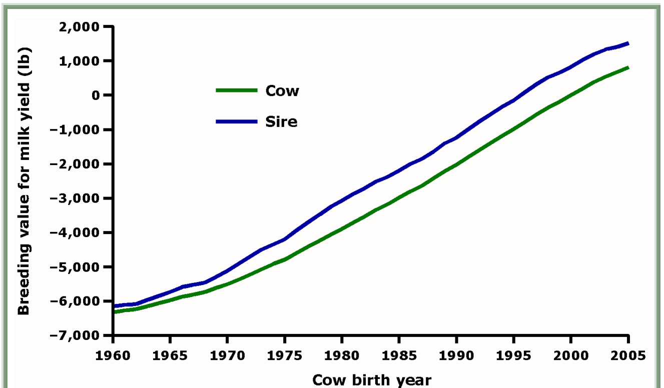

Figure 8. Trend in Holstein breeding value for milk yield.

In 2008, genotypic data and genomic predictions were introduced by BFGL and AIPL, exactly a century after phenotypic data collection began. With this new tool, dairy cattle breeders can greatly speed the rate of improvement for economic traits by tracing Mendelian inheritance for thousands of genetic markers. As phenotypic data sets, genotypic data sets, and numbers of markers expand, more of the actual genes that affect important traits will become known.

"Much is uncertain about how closely the human beings who will do the work will come to achieving that which is biologically possible, but at least a good beginning has been made." (Lush, 1956)

AIPL history on the web

History and photos (1908–present)
Evaluation changes (1989–present)
Laboratory names, evaluation schedule, and computing sites
Past AIPL staff
Top bull lists (1974–present)

References and additional resources

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