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A 100-Year Review: Methods and impact of genetic selection in dairy cattle—From daughter–dam comparisons to deep learning algorithms[1]

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ABSTRACT

In the early 1900s, breed society herdbooks had been established and milk-recording programs were in their infancy. Farmers wanted to improve the productivity of their cattle, but the foundations of population genetics, quantitative genetics, and animal breeding had not been laid. Early animal breeders struggled to identify genetically superior families using performance records that were influenced by local environmental conditions and herd-specific management practices. Daughter–dam comparisons were used for more than 30 yr and, although genetic progress was minimal, the attention given to performance recording, genetic theory, and statistical methods paid off in future years. Contemporary (herdmate) comparison methods allowed more accurate accounting for environmental factors and genetic progress began to accelerate when these methods were coupled with artificial insemination and progeny testing. Advances in computing facilitated the implementation of mixed linear models that used pedigree and performance data optimally and enabled accurate selection decisions. Sequencing of the bovine genome led to a revolution in dairy cattle breeding, and the pace of scientific discovery and genetic progress accelerated rapidly. Pedigree-based models have given way to whole-genome prediction, and Bayesian regression models and machine learning algorithms have joined mixed linear models in the toolbox of modern animal breeders. Future developments will likely include elucidation of the mechanisms of genetic inheritance and epigenetic modification in key biological pathways, and genomic data will be used with data from on-farm sensors to facilitate precision management on modern dairy farms.

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THE BUILDING BLOCKS

Performance Recording

Pedigree records and performance data were the key building blocks in developing effective genetic selection programs in the pre-genomic era, as noted in Appendix Table A1. Pedigree records traced back to the origin of breed societies in the late 1800s, and widespread collection of performance data began shortly thereafter, with the encouragement of early dairy industry pioneers such as W. D. Hoard. The first statewide association for recording milk weights and analyzing butterfat samples was formed in Michigan in 1905, and by 1908, the United States Department of Agriculture (USDA) Bureau of Animal Industry began organizing local and state cow testing associations into the national Dairy Herd Improvement Association (DHIA). Responsibility for this effort was transferred to federal extension workers in 1914, and participation in milk testing grew rapidly (VanRaden and Miller, 2008), as shown in Figure 1.

Monthly DHIA testing was the norm for many decades, but now about two-thirds of dairy farms use labor-efficient a.m./p.m. testing plans, in which milk samples are taken at alternate times each month. Future strategies that focus on more frequent DHIA sampling of recently fresh cows or cows in the highest-producing pens may provide more useful data for cows that are at peak efficiency and at the greatest risk for common health disorders. Electronic measurement of data, via radiofrequency identification (RFID) sensors and inline sampling systems, has replaced manual entry of pedigree and performance data, as shown in Figure 2.

Local bull associations were common during the 1920s and 1930s, until the widespread adoption of AI in the 1940s, when dozens of regional AI cooperatives were formed. Because virtually all traits of interest in dairy cattle are sex-limited, genetic evaluation of a bull's own

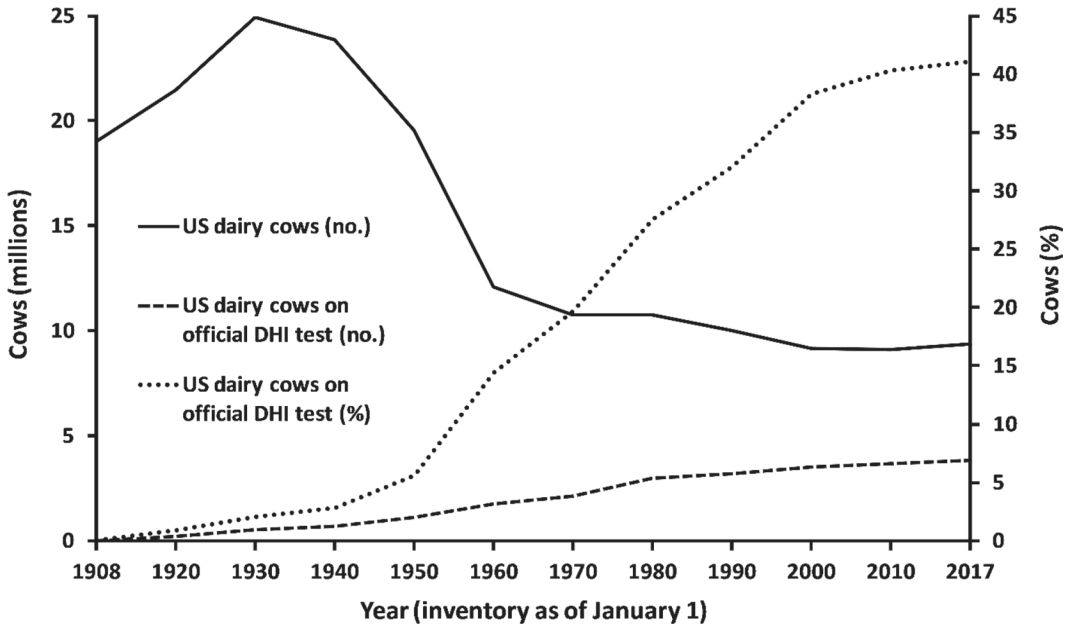
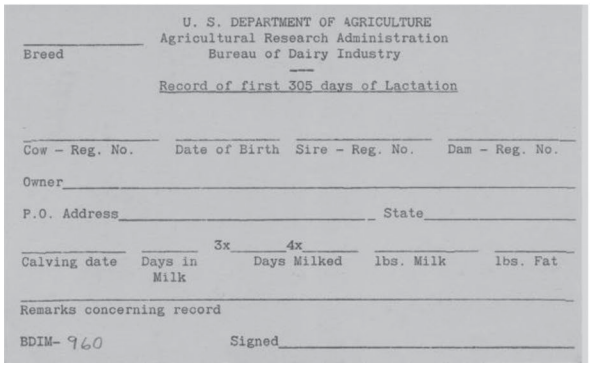


Figure 1. Participation in milk recording programs in the United States, from 1908 to 2017.



U. S. DEPARTMENT OF AGRICULTURE
Agricultural Research Administration
Breed Bureau of Dairy Industry

Record of first 305 days of Lactation

Cow – Reg. No. | Date of Birth | Sire – Reg. No. | Dam – Reg. No.

Owner

P.O. Address State

Calving date | Days in Milk | 3x 4x Days Milked | lbs. Milk | lbs. Fat

Remarks concerning record

BDIM- 960 Signed

Figure 2. Recording of performance data for dairy cows then (1936, left panels) and now (2017, right panel).