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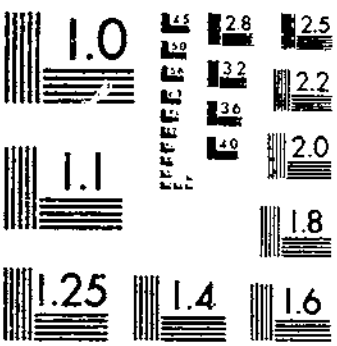

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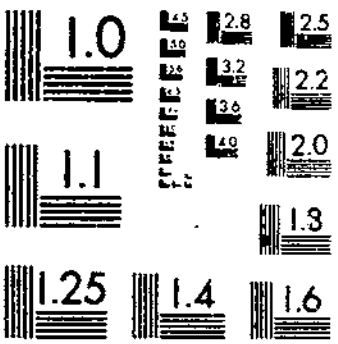

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Technical Bulletin No. 1220

BREEDING EXPERIMENTS WITH HOLSTEIN-FRIESIAN CATTLE

Results of 35 Years' Research at Beltsville

United States Department of Agriculture

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Prolog

The data summarized in this study are complete for the first five generations of production-proved sire breeding, and data on three additional generations are included although all females in these generations have not completed production records. Results are now sufficiently indicative to warrant the preparation of a report on this longtime breeding experiment so that it will be available to dairy cattle breeders, dairymen, and students of breeding.

The feeling persists that for a long time the matter of breeding dairy cattle to improve their producing capabilities will continue to be the responsibility of the men who operate dairy herds and farms as a business. Properly conducted breeding research can make substantial contributions both as to procedures and also in the form of potential genetic material, but the nature of the dairy cattle breeding business is such that much will depend on the skill and judgment of individual breeders and members of bull selection committees who are responsible for the sires selected for artificial breeding. The results of experience in following a definite program of dairy cattle breeding over a long period, reported here, should be helpful to those on whom this responsibility rests.

BREEDING EXPERIMENTS WITH HOLSTEIN-FRIESIAN CATTLE

Results of 35 Years' Research at Beltsville, Md.

By M. H. Fohrman, Animal Husbandry Research Division,
Agricultural Research Service

Introduction

Breeding investigations with dairy cattle were begun by the U.S. Department of Agriculture in 1917 at the dairy experiment station at Beltsville, Md.[1] The late B. H. Rawl, then Chief of the Dairy Division, conceived the idea of developing scientific information in dairy cattle genetics by studying the subject directly, through the use of experimental herds of cattle. The object of this experimental work was to afford breeders and dairy farmers a more complete understanding of the laws of heredity as they apply to the breeding of dairy cattle for economical and profitable production of milk and butterfat. It was felt that with a knowledge of genetics as a basis for conducting a breeding program and a successfully demonstrated plan of procedure for applying such knowledge, dairymen would be able to carry on the breeding of high-producing dairy cows with greater assurance of success.

At that time, as at present, the dairy cattle breeding business was hazardous because a high percentage of the female offspring failed to be profitable producers. In later years, as evidence from cow-testing association herds was accumulated and analyzed, it was found that the cows in these herds were distributed about evenly in three milk-producing classes. One-third earned a profit, one-third broke even, and the other third failed to produce sufficient milk to pay for their keep. This last third could, of course, be identified and disposed of after they were milking, but by that time they represented a considerable capital investment by their owners, only a part of which would be refunded by the butcher.

[1] These investigations were originally a part of the research program of the Dairy Division of the Bureau of Animal Industry. The responsibility for this research was transferred to the Bureau of Dairy Industry when it was established in 1924, and then to the Dairy Husbandry Research Branch of the Agricultural Research Service when the Department was reorganized in November 1953. The Dairy Husbandry Research Branch became a part of the Animal Husbandry Research Division in February 1957.

A business with so large a proportion of failures in its operations could hardly be considered efficient; yet such was the condition of the dairy cattle breeding industry. Later on, when more interest was aroused and bull proving became more popular, the records disclosed a similar three-class performance for dairy sires—one-third raising production, one-third about maintaining it, and one-third actually lowering production—as measured by the records of the daughters of a sire when compared with the records of their dams.

That was the situation at the time these breeding experiments were conceived, although at that time the volume of records was not great enough to make it as impressive as later. The need for a better breeding procedure was evident. Studies of breeding operations at that time would not supply satisfactory information, as few breeding establishments were following a definite and nonselective testing program. Record making was largely for advertising purposes and hence was highly selective. Few breeders remained in the business long enough to establish special merit in their cattle. There was much maneuvering among breeders to keep abreast of popular trends occasioned by the publicity attending a high-production record or a successful show-ring performance. Testing for high records under forced conditions was approaching its zenith, and the services of test-cow feeders and handlers were at a premium. Pedigrees were built up by record combinations and padding, and the whole procedure rolled itself into a huge "snowball" of ballyhoo, showmanship, and sensational advertising, which swept the fraternity into the hysteria of fabulous prices for young, untried bulls of fashionable bloodlines, and astounding pedigrees. But that snowball smashed on the rock of commonsense, and after a sobering letdown dairymen were ready for something built on a more solid foundation. For these reasons, the Dairy Division inaugurated breeding investigations with herds where environment could be stabilized, testing made all-inclusive, and selection eliminated.

During 1917 considerable time was spent in making a preliminary survey of the dairy cattle breeding field. Breeders were contacted and their problems discussed. Some opinion was developed as to what information was needed to assist the breeders in their work. At that time there was wide discussion of the relative merits of outbreeding, linebreeding, and inbreeding for improving dairy cattle. Plans were laid to develop information in the course of the breeding investigations which would give a fair estimate of the importance of the system of mating followed during a program of herd improvement by breeding.

One fundamental question to which an answer was to be sought was how to reduce the number of unwanted low-producing females and poor-transmitting males among the progeny of our herds. A reduction from 1 failure in 3 to 1 in 5 would be worthwhile, and to 1 in 10 would be very good. It was decided that the most hopeful approach to a solution of this problem was the use of production-proved sires—those which had already demonstrated their transmitting ability through the production performance of their daughters. Producing ability was considered as paramount, since it is the sale of the milk and butterfat produced by the herd that makes its maintenance and the owner's income secure. Even the owners of well-

advertised breeding herds seldom get more than 10 percent of their gross income from the sale of surplus stock, and this is usually dependent on a satisfactory production performance for the herd.

Breeding Projects With Dairy Cattle

The breeding projects reported here were set up in 1918. The breeds selected were Holstein-Friesian and Guernsey. These projects contemplated the continuous use of production-proved sires to concentrate inheritance for high levels of milk and butterfat production. This procedure was predicated on the theory that the valuable sire was one that had a large number of hereditary factors controlling high levels of production. Furthermore, if these proved sires all had a similar factorial makeup, the factors for low production that were left in the herd by previous sires would be gradually replaced through the continued use of proved sires for a number of generations. This theory was developed from studies of advanced-registry and register-of-merit production records made by the Dairy Division.

With the proved sire as the basis for improvement, the projects were mapped so that comparative information would develop on outbreeding, linebreeding, and inbreeding.

The project outlines and plans were discussed at some length in an article in Hoard's Dairyman.[2] In that article it was stated that the need of carefully planned experiments had long been felt, but the length of time and the number of animals required had made it impossible for a single breeder to attempt it. The article was written soon after the foundation Holstein herd had been assembled at Beltsville. The plan outlined then has been largely adhered to, but Jerseys were substituted for Guernseys on part of the project and the crossbreeding features were omitted. Additional inbreeding was added later as a genetic check on the proved sires. The studies discussed in the following pages pertain only to the Holstein phases of the work. The Jersey data are in the process of analysis. Also, specific discussions of the results of the linebreeding research are not included in this publication.

Procedure for Conducting the Holstein Breeding Experiments

The principal project with Holstein-Friesian cattle called for the continuous use of unrelated production-proved sires to develop a strain that would steadily improve in its inheritance for a high level of milk and butterfat production. This was the outbreeding phase, and linebred groups were to be bred from the same stock so that both the outbred and the linebred groups would start from the same basis of heritage. The linebred groups were to be produced by mating sons of the various proved sires to the half sisters of their dams (relationship of nephew to aunt). In this manner outbred groups

[2] ANONYMOUS. DAIRY CATTLE BREEDING EXPERIMENTS TO BE FINANCED AND CARRIED ON FOR A LONG PERIOD BY THE U.S. DAIRY DIVISION. Hoard's Dairyman 57: 544-545, illus. 1919.

and linebred groups would come from the same dams. To illustrate, the daughters of sire 1 would be bred to unrelated sire 2, and the progeny would be the outbred group. At later matings these same daughters of sire 1 would be bred to a son of sire 2 that was out of a daughter of sire 1, the resulting progeny thus being a linebred group obtained by the mating of nephew to aunts. This procedure was to be repeated for each generation.

Another procedure, followed in a limited way, was to breed the first daughters of proved bulls to their own sires. This afforded an opportunity to delay the introduction of a new proved sire until more of the daughters of his predecessor were of breeding age. By holding off in this manner there was greater assurance that the new bull would be able to reach his project quota of daughters by serving more cows during his first 2 years in the herd. The results of these short interludes of inbreeding might also be justified as providing a closer check on the genetic makeup of the sires and possibly unmasking hidden recessives. Inbred daughters were developed under standard conditions and were included in this generation study as some of them contributed daughters by other project bulls.

Certain difficulties and hazards continuously threaten the success of even the most carefully planned breeding projects with large animals such as dairy cattle, and it might be well to enumerate them for the benefit of those who are impatient at the slow rate at which results are forthcoming.

There is always a threat of interference and interruption by outbreaks of disease that may occur in spite of constant vigilance. During this work, infectious abortion, tuberculosis, and mastitis have all been encountered and have taken some toll in passing. A severe outbreak of TB in 1935 and 1936 was a serious threat to the further progress of this experiment, but by means of quarantine procedure and recruitment of some females from the linebred groups it was possible to retain sufficient numbers to carry on the major objectives.

One bull used to produce linebred daughters developed a very satisfactory proof and had limited service as a proved sire later on. This came about when the wartime restrictions on travel caused some delay in replacing a proved bull that died after a short period of service.

Occasionally young bulls were used to settle problem cows and heifers and a few of the resulting females were included in this analysis in order to make it as nearly complete as possible.

With proved sires brought in at advanced ages there were delays due to sterility, and accidental losses of important sires have reduced numbers of offspring in some groups.

The fact that the reproduction rate in cattle is slow made it necessary to undertake the projects with the certainty that results could be attained only after many years.

The maintenance of environmental conditions without change over a long period has been a difficult problem, not only because of changing personnel but also because of a natural desire to utilize the steadily developing knowledge of the factors that influence production.

The necessity for upholding the standard of excellence of sires brought in, the sustaining of enthusiasm while awaiting slow-moving results, and the suppression of zeal to push the better and neglect

the poorer groups, were all minor factors that needed careful watching to maintain parity of opportunity for all generations, since the human element cannot be entirely overlooked where the milking and general care of cattle are concerned.

The formulation of procedure for conducting these projects required careful consideration. Once they were launched according to a certain plan, there was no possibility of altering the procedure materially without sacrificing the completed part of the work. It is the changing of methods and of environment that most often discounts the value of breeding studies based on results in commercial herds. These changes in herd management are often due to changes in economic conditions. In order to stand the test of time it was deemed best to make all requirements of procedure moderate. No extreme conditions were established, as these are always difficult to maintain over a period of years, and success depends too often on the skill and enthusiasm of the individual. Moderate requirements can usually be met, even where management personnel is subject to change.

To meet the demands of good experimental procedure it was necessary that no culling or selection of females would be practiced after the foundation herd was established. All female progeny of the various sires were raised and developed without regard to the appearance or producing ability of themselves or their dams. The results are based on unselected and unculled groups. The objective was to study inheritance and transmitting ability for production of all animals in the herd under uniform conditions.

Following the above principle, all the female calves were retained and raised under conditions that should insure satisfactory growth up to producing age. Calves were separated from their dams shortly after birth, placed in small pens in the calf barn, and fed by hand. Whole-milk feeding continued up to 4 weeks, at which time skim milk was substituted. Grain and hay were offered as soon as the calves would eat these feeds. At 6 months of age skim-milk feeding was discontinued. This procedure was general, but the feeding of whole milk was continued longer than 4 weeks if the calf lacked vigor or was retarded by sickness. Corn silage was fed to calves past 6 months of age in the first few years, but for convenience this practice was changed and grain and alfalfa hay later made up the whole ration after skim-milk feeding had been discontinued. The quantity of grain was varied from time to time and ranged from 2 to 5 pounds daily for animals 8 to 12 months of age, but sufficient nutrients to afford good growth were fed at all times. The most satisfactory procedure after skim-milk feeding was discontinued was to allow a maximum of 3 pounds of grain daily and free access to alfalfa or mixed hay. It was known that a fairly wide range of rations would insure satisfactory growth.

At a year old, heifers were moved into the herd barns. Silage in winter and pasture in season were then added to the ration. First breeding of heifers was in the 15th month, for calving at approximately 2 years of age.

It was decided that the measure of producing ability would be the amount of milk and butterfat produced in 365 days under standardized conditions. When the projects began, the 7-day production

record was still in use by many breeders, and the yearly records that were being made in some of the leading herds were on a selective basis. Milking four times daily for 365 days was in favor where much of the testing was being done. Few breeders were interested in 305-day production because the record was at a disadvantage when compared to the full-year record. The later trend toward the 305-day record was not yet apparent, and herd testing was not even discussed. If the program were being established today, the 305-day test would be adopted, largely because it would hasten results by shortening the calving interval. With this background the 365-day record was set up as the standard, and the records were made on three milkings daily until late in 1951. Since then the procedure has been two milkings daily for 305 days. All records used in this study that were not actually made on two milkings daily for 305 days have been adjusted to that basis.

The cows were kept in box stalls. Feeding was based on size of the cow (maintenance), rate of milk production, and butterfat test of the milk. A modified Savage feeding standard was used to determine the nutritive requirements, based on weight and production at the beginning of each month, and feeds were adjusted accordingly. Originally, the feeds used were corn silage, alfalfa hay, wet beet pulp, and a grain mixture with a digestible protein content of 18.2 percent. In July 1933 it was decided to mix the dry beet pulp with the grain in the proportion of 1 to 4, which reduced the digestible protein content to 15.5 percent. This assured greater accuracy in feeding the beet pulp and made the proportion the same for all cows.

Pasture is variable in the Beltsville locality, and as there is no assurance of adequate pasturage from year to year, and also because there is no accurate means of determining the amount of nutrients obtained from pasture when other rations are being fed during the pasture season, the cows on test had no pasture during their test years. Exercise was permitted in a dry lot. All cows were encouraged to eat hay and silage by offering them slightly more than they would consume, and the grain ration was apportioned to make up the rest of the nutrients required for maintenance and production. No excessive feeding methods were followed, and no effort was made to pamper individual animals with special feeds. During the test year the cows were bred in the fifth month of lactation when on 365-day test and in the third month when the change was made to 305-day records.

All cows were put on test at the first calving, if the calving was normal, and in as many lactation periods thereafter as the barn facilities would allow, but there was not sufficient space to have all cows on test each year.

All cows were milked by hand until November 1928, when part of the herd was changed to machine milking. For a period after June 1931 the entire herd was milked by machines, but provision was made to have every cow milked by hand during at least one lactation period. The TB outbreak in 1936 made it necessary to milk cows in quarantine by hand. From April 1938 until June 1950 only first-calf heifers were machine milked.

Every effort was made to provide conditions of environment and management that could be kept continuously uniform. The feeding and handling were such as to enable cows with good inheritance fully

to express their ability to produce. A restrictive or variable environment would have defeated the purposes for which the projects were set up. Unfavorable environment could have limited the level of production.

Production records during test years were made under the supervision of the University of Maryland and in accordance with the rules of the Holstein-Friesian Association of America.

Records made by cows under 6 years of age when used for comparative purposes were corrected to a mature-age-equivalent basis by use of correction factors developed at Beltsville. Records made by cows with blind quarters were noted, but no correction was attempted, because the shrink due to a nonfunctioning quarter cannot be determined definitely. Records for short lactations were used as made, because the conditions were favorable for a complete record and the fault was considered as being in the cow. Sickness in cows was noted and they were given proper treatment, but no allowance was made for any nondeterminable loss in production. If the interference was severe the trial was repeated in the next lactation period.

Temperature control was not possible with the equipment at Beltsville. No artificial means were used to make the test cows more comfortable during the summer months, though no doubt high temperatures and humidity resulted in lower production levels for some cows and particularly for those freshening in the spring or early summer. While all cows were housed under the same conditions, extremes of temperature and humidity affected cows at different periods of their lactations, but no attempt was made to correct for such effects. All abnormalities were recorded.

Thus, every effort was made to give each cow, no matter how poor a producer she may have been, the chance to produce under good management practices. The cow with a capacity for production of 350 pounds of butterfat had the same care and management, and the same opportunity to produce, as the cow with a capacity for production of 800 pounds. The only controlled variation was the amount of nutrients fed. An attempt was made to feed each cow approximately 10 percent more nutrients than her calculated requirements, in order that limited production might not be attributed to limitation of feed.

Deciding Which Records To Use

In studying inheritance of milk production the investigator is usually confronted with the problem of determining, in cases where animals have more than one production record, which record most accurately measures producing ability. Opinion is divided as to whether the highest single lactation period record, an average of all lactation records, or the lifetime production record should be used to define producing ability.

In commercial herds where the sale of milk products is the source of income, the animal that has a good lifetime production will be more profitable than the animal that is a good producer for only one or two lactation periods; but where the selection of breeding stock is important or where an analysis of the inheritance of producing ability is sought, it seems essential to use the standard that is most nearly free from interference by environmental factors.

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Lifetime production may be interfered with by breeding troubles, improper feeding, damage to the udder, or other injuries, none of which have anything to do with inheritance for level of production. Lifetime performance may be as much a measure of good herd management as of inheritance. Very often the cow that has a good lifetime record is one that was fortunate in escaping injury and attacks of disease. Whether these animals possess an inherent resistance to disease or an inheritance for superior constitution or hardiness that enables them to be good producers year after year is questionable.

Lifetime averages tend to reduce the variability of groups of daughters, and as this is an important point in studying the transmitting ability of sires, it would appear necessary that variance be considered without the modification that averaging would introduce.

The planned procedure in these breeding investigations was to start all cows on test under standard environmental conditions when fresh with first calf, and as often thereafter as facilities would permit. The mature record would be the best standard for measuring producing ability, if it could be safely assumed that all would go well; but unfortunately some animals died or became sterile before reaching maturity, others suffered injuries or udder damage that may have interfered with the full expression of their inherited ability, and still others were started on test during years when difficult calving or other uncontrollable factors interfered with the normal functioning of their milk-producing equipment. These latter items furnished the principal reasons for starting cows on test with first calf. The probabilities were thought to be greater that the average animal would be sound and normal in her first lactation than at any subsequent lactation period; but even the first lactation period is subject to interference by some of those physiological derangements.

The use of heifer records only might be suggested as a satisfactory solution, but under the best of conditions all animals do not calve at the same age, nor do they all calve normally the first time. Furthermore, if slow maturity should be a characteristic of any particular group, the use of heifer records alone would act to the disadvantage of members of this group.

Age-correction factors help to overcome the effect of age differences, and their use is warranted in ironing out unavoidable differences in age of first calving and also in making heifer records comparable with mature-age records.

After weighing all the above facts and theories it was deemed best to use the highest records in all cases, either actual mature records or the immature records calculated to maturity, in the analysis of the data.

Operation of the Holstein Project

The Beltsville proved sire breeding project was originally designed to be operated on a single-sire-per-generation basis. In the early years the herd was relatively small, which meant that the period of service of a bull would need to cover a span of 4 or 5 years in order to insure an adequate number of female progeny to operate the project according to the original plan. The first and second sires met

this requirement fairly well, contributing 33 and 31 daughters, respectively, but this was not true of the next 2 bulls. When consideration is given to the advanced age of bulls when proved, it is noteworthy that five of the seven bulls selected had periods of service of sufficient length to insure a dependable contribution to the advancement of the project.

When the third and fourth sires were lost before they had met the expected requirements in number of progeny, the sequence of single-sire generations was broken. In order to maintain the herd, sire No. 5 was mated to daughters of the three preceding bulls, thereby producing daughters with three, four, and five generations of inheritance from proved sires.

About the time the seventh purchased proved sire had daughters of breeding age, the rapid growth of artificial breeding had developed a highly competitive situation in the proved bull market. However, service to bulls with satisfactory transmitting ability was available from sires that were being used by artificial breeding studs. Since the original plan of single-sire generations had already been modified, it seemed logical to continue the study by utilizing the service of selected sires in bull studs. This was done through the generous help of the First Pennsylvania Artificial Breeding Cooperative, Lewisburg, Pa.; NEPA Artificial Breeding Cooperative, Tunkhannock, Pa.; SE Pennsylvania Artificial Breeding Cooperative, Landisville, Pa.; and the New York Artificial Breeders' Cooperative, Ithaca, N.Y.

Reported here is a summary of the results of about 35 years of carefully controlled breeding research designed to measure the effects of using production-proved sires to raise the level of production. The only selection practiced was in the choice of bulls. All females were raised and afforded equal opportunity to produce and reproduce under standardized environmental conditions that were maintained as nearly constant as was possible during the entire period covered by the experiment.

Production-proved sires that were purchased to carry on this breeding project are referred to by numbers. These numbers follow the order in which they were brought into the herd. Beltsville-bred bulls that were used in emergencies, and whose progeny became part of the project by having daughters sired by other proved sires, are identified by Beltsville herd numbers. Production-proved sires in service in artificial breeding studs, whose semen was used during the later years of the experiment, are identified by stud code numbers.

The analysis is on a generation basis and includes all females regardless of level of production.

The Foundation Herd

The foundation herd of Holstein cattle was made complete by supplementing the small group of animals already at Beltsville with three lots of females purchased in the spring of 1918, in Minnesota, Ohio, and New York. These females were selected because of their close descent from well-known sires of that day whose daughters were attracting attention with their large milk and butterfat production records. There were 22 cows in this purchased group, and

7 are represented by female descendants. The purchased cows were carrying six female calves, and three of these became foundation cows with female progeny. The Beltsville group consisted of three daughters of Johan Woodcrest Lad 11th, two granddaughters of the same sire, and eight daughters of bulls used before the breeding project started. Seven of these 13 are represented in the project by female descendants.

Of the 41 original foundation cows, 34 completed production records that averaged 542 pounds of butterfat. Only half (17) of these females produced daughters for this project. This half of the foundation herd, which formed the basis of the whole analysis, averaged 542 pounds of fat. They ranged from 765 to 377 pounds.

A complete story of the foundation herd has been published.[3]

Sires Used

The production-proved sire has now reached a position of prominence in all general discussions of cattle breeding and also in the literature, and it is necessary to recall the date of the inauguration of these breeding projects (1919) in order to get a true picture of the problem of selecting an adequately proved sire when this work was started.

Few, if any, breeders in the country were attempting to prove the transmitting ability of their bulls by nonselective testing. Very few bulls with daughters in milk were available for purchase. Selective testing and lack of comparable records on the dams too often made impossible a satisfactory assay of a sire's ability. Cow-testing associations were not so numerous nor so continuous as today, the herd test had not yet been conceived, and yearly production testing was limited. Holstein-Friesian bulls that were prominent in the literature and advertising of the day were upheld by fashionable pedigrees or by high records of some of their daughters, and often these records were for only 7 or 30 days.

This situation meant a long and careful search to discover a bull for which there were sufficient data to afford a true indication of his transmitting ability. The information available on the bulls at the time of their purchase is shown below.

Denton Colantha Sir Rag Apple 87426 (Sire No. 1)

In the fall of 1919 Denton Colantha Sir Rag Apple 87426 was purchased from Benjamin Pringle, of Mayville, N.Y. He was put in service on this project in October 1919. At the time of purchase he was 8½ years old, and he continued in service at Beltsville until he was past 16 years of age. Evidence available in the cow-testing association records of his daughters indicated that he was an acceptable sire for use on this project.

According to the records of the breed secretary's office, 52 daughters were registered as sired by Denton Colantha Sir Rag Apple and

[3] Fohrman, M. H., and Graves, R. R. EXPERIMENTS IN BREEDING HOLSTEIN-FRIESIAN CATTLE FOR MILK AND BUTTERFAT PRODUCING ABILITY . . . U.S. Dept. Agr. Tech. Bull. 677, 81 pp., illus. 1939.

born before October 1, 1920. Six of these were registered by the original owner of this bull; 38 by Mr. Pringle, from whom the bull was purchased; and 8 by neighbors of Mr. Pringle. Some of these animals were sold and subsequently production information on them appeared in the advanced-registry lists of the Holstein-Friesian Association. The six in the original owner's herd were never tested for milk production. The records of the remaining 46 show that 3 died before calving, 1 was a nonbreeder, 2 died on test, and 32 made advanced-registry production records. Seven of the remaining eight were sold into herds where no testing was done. Considering the then-prevailing custom of selective testing, the ratio of these 32 to the entire get was unusually high.

The 32 daughters completed a total of 70 advanced-registry records with a mature-equivalent average of 602 pounds of butterfat. Many of these records were made under dairy-farm conditions in ordinary cow ties, with twice-a-day milking, and moderate feeding. Others were made by daughters sold into herds where they were milked more than twice daily and given a better opportunity to express their inherited production ability. For convenience, these 70 records have been arranged in tabular form (table 1), divided into 305- and 365-day divisions, and listed, by age groups, according to whether the cows were milked twice daily or more than twice daily. These averages are based on actual production with no corrections.

TABLE 1.—*Summary of 70 records made by 32 daughters of Denton Colantha Sir Rag Apple that were sired in herds where he was used prior to 1919*

305-DAY RECORDS

Age class (years)	2 daily milkings				More than 2 daily milkings			
	Records	Average production			Records	Average production		
		Milk	Butterfat			Milk	Butterfat	
	Number	*Pounds*	*Percent*	*Pounds*	*Number*	*Pounds*	*Percent*	*Pounds*
2	8	10, 308	3. 39	349	3	11, 932	3. 57	425
3	7	11, 212	3. 26	366	2	14, 062	3. 65	511
4	7	11, 595	3. 47	402	7	14, 262	3. 51	498
Mature	5	11, 590	3. 57	413	2	18, 136	3. 63	660
Total or average	27	11, 114	3. 41	379	14	14, 288	3. 56	507

365-DAY RECORDS

2	2	11, 419	3. 25	372	8	15, 132	3. 40	512
3	3	13, 811	3. 34	455	5	17, 697	3. 38	598
4	2	14, 829	3. 42	505	1	20, 038	3. 79	767
Mature	3	13, 606	3. 39	461	5	20, 636	3. 46	716
Total or average	10	13, 474	3. 35	450	19	17, 514	3. 43	602

Some of the age groups are small in number, but it is interesting to note the consistent differences in production between the groups that were milked twice daily and the others. This difference may be a fair measure of the effect of changed environment as some of the cows made records in both groups, whereas others were tested solely in one or the other. On a mature-equivalent 365-day basis, the 37 records under twice daily milking average 528 pounds of butterfat, whereas the other 33 average 685 pounds.

Further study revealed that 19 of these daughters were from dams without official records, but the other 13 were from tested dams. On a mature-equivalent 365-day basis, the records of these groups are as follows:

Group	Average production		
	Milk	Butterfat	
	Pounds	*Percent*	*Pounds*
19 daughters from untested dams	17,803	3.51	619
13 daughters from tested dams	19,553	3.38	652
13 dams of the tested daughters	19,533	3.40	662
Difference	+20	−.02	−10
Daughters better than dams—number	7	9	6

The average for dams and daughters is approximately the same. The dams of the seven daughters that failed to outproduce their dams all had records above 650 pounds of butterfat. Five of the six dams whose daughters exceeded their production had records below 600 pounds of butterfat.

Most of the above information had developed before this sire's daughters that were bred at Beltsville came into milk, but of course only part of it was available at the time of his purchase.

Varsity Derby Matador 234809 (Sire No. 2)

Sire No. 2 was purchased from the North Platte substation of the University of Nebraska. He reached Beltsville July 1, 1925. His daughters in the North Platte herd were tested for advanced-registry records and were milked four times daily. Testing in that herd had previously been official 7-day records, and some of the dams of his daughters left the herd before yearly testing was begun. Indications were that all daughters were being tested and, at the time of purchase, production information was available on eight daughters, seven with first-calf records, and the eighth with a second-calf record because she had been bred too soon and her first record was cut short.

On four milkings daily for 365 days, these eight daughters averaged 17,020 pounds of milk and 633 pounds of butterfat, at an average calving age of 2 years 10 months. Only four dams had records to compare with the daughters. On a mature-equivalent, 365-day, four-times-daily milking basis, the following proof resulted:

Group	Average production		
	Milk	Butterfat	
	Pounds	*Percent*	*Pounds*
8 daughters	21, 115	3. 73	785
4 daughters	22, 744	3. 67	831
4 dams	20, 546	3. 50	720
Difference	+2, 198	+. 17	+111
Daughters better than dams—number	4	3	4

This proof would appear rather meager under present-day conditions, but repeat records of these daughters and incomplete records on additional daughters indicated that the information was dependable. Production records for the first eight daughters ranged from 576 to 727 pounds of fat. In 1925 progeny-tested sires were scarce, as DHIA proving of bulls had not been started at that time.

Pride of the Bess Burkes 294574 (Sire No. 3)

Pride of the Bess Burkes was purchased from the State School and Home herd at Redfield, S. Dak., in 1927. He was sent to the U.S. Dairy Field Station at Huntley, Mont., and moved to Beltsville, January 5, 1929. He died on March 27, 1930.

The Redfield herd was large and most cows were being tested in Advanced Register and were milked four times daily. At the time the bull was purchased, records were available on 14 daughters. In their first lactations they had averaged 16,830 pounds of milk and 573 pounds of fat, calving at 2 years 10 months. Three of these were from dams that had no records. On a mature-equivalent, 365-day, four-times-daily milking basis, the following proof developed:

Group	Average production		
	Milk	Butterfat	
	Pounds	*Percent*	*Pounds*
14 daughters	21, 100	3. 41	718
11 daughters	20, 300	3. 44	696
11 dams	19, 210	3. 24	620
Difference	+1, 090	+. 20	+76
Daughters better than dams—number	5	8	8

There was a wide range in the levels of production of both daughters and dams, and because of the size of the herd it was difficult to determine the amount of selection practiced in the testing program. Later evidence provided a basis for our belief that this bull had sired several daughters at Redfield that had the same production deficiency manifested by two of his daughters in the Beltsville herd. He was also heterozygous for color, but did not sire any red and white calves at Beltsville. However, during his brief period of service in the Huntley herd he sired a pair of female twins, one of which was red and white.

In the Redfield herd, Pride raised the percentage of butterfat from 3.24 to 3.44, and at Huntley from 3.67 to 3.80.

Count Piebe Hengerveld Ormsby 444324 (Sire No. 4)

Sire No. 4 was purchased from M. M. Slocum of Barneveld, N.Y., on October 16, 1930.

Information was available on 10 of his daughters that had completed first-calf records. They were all milked four times daily for 365 days, and their production ranged from 12,700 to 18,000 pounds of milk and from 488 to 609 pounds of butterfat. Their average was 14,982 pounds of milk and 550 pounds of fat, with an average test of 3.68 percent. Mature-equivalent averages were about 20,000 pounds of milk and 730 pounds of fat.

The four-times-daily milking procedure in the Slocum herd began when the daughters of Count freshened. It was possible to develop a comparison of five daughters and dams, and all records were adjusted to a 365-day, three-times-daily milking basis with the following result:

Group	Average production			Age
	Milk	Butterfat		
	Pounds	*Percent*	*Pounds*	*Yr. Mo.*
5 daughters	12,687	3.66	462	2 5
5 dams	12,619	3.44	428	2 5
Difference	+68	+.22	+34	
Daughters better than dams—number	4	4	4	

The level of the daughters compared favorably with the level in the Beltsville herd at that time.

Chief Piebe Ormsby Burke 444088 (Sire No. 5)

Sire No. 5 was purchased from H. A. Snyder of Montoursville, Pa., on May 14, 1932. This herd at the time was in DHIA, but some cows were being milked three times daily and were advanced registry tested. In addition, some daughters and dams had been milked three times daily for 30 to 45 days at the beginning of lactation. One daughter was sold, and the new owner milked her four times daily. Her record when she calved at 3 years 2 months was 18,492 pounds of milk and 739 pounds of fat in 365 days. Three daughters in the Snyder herd made mature-equivalent butterfat records of 882, 792, and 695 pounds in 365 days when AR tested on three milkings daily.

Group	Average production		
	Milk	Butterfat	
	Pounds	*Percent*	*Pounds*
13 daughters	16,274	3.78	615
13 dams	14,685	3.69	546
Difference	+1,589	+.09	+69
Daughters better than dams—number	8	6	9

From the complete data available, a final appraisal was made on 13 pairs, based on their mature-equivalent performance on 2 milkings daily for 365 days (p. 14).

Douglas Buttercup Hark 660575 (Sire No. 6)

Sire No. 6 was purchased from Folmer C. Hanson of Cedar Falls, Iowa, and arrived at Beltsville, December 12, 1938. The general practice in the Hanson herd was to milk most cows three times daily after freshening, for periods varying from 40 to 180 days. The herd was well managed, and most of the three-times milking was during the fall and winter months. The Holstein-Friesian World on May 12, 1942, reported the award of 2,000-pound fat certificates on seven daughters of Douglas Buttercup Hark, an indication of the quality of the herd handling.

From the records available at the time of purchase, a 14 dam-daughter proof was developed on Douglas with all records adjusted to a mature-equivalent, 305-day, two-times-daily milking basis:

Group	Average production		
	Milk	Butterfat	
	Pounds	*Percent*	*Pounds*
14 daughters	14,694	3.89	571
14 dams	12,637	3.85	479
Difference	+2,057	+.04	+92
Daughters better than dams—number	10	10	11

Douglas was in service in a second herd when he was purchased. Management practices here differed from those in the Hanson herd, and the herd was operating under the Herd Test. The point of interest in this matter is that in November 1946 the Holstein-Friesian Association issued the following proof on Douglas based on Herd Test records of daughters in the second herd:

Group	Average production		
	Milk	Butterfat	
	Pounds	*Percent*	*Pounds*
24 daughters	9,540	3.58	342
24 dams	10,690	3.46	370
Difference	−1,150	+.12	−28

Rose Hill Emperor Governor 743892 (Sire No. 7)

Rose Hill Emperor Governor was owned jointly by John J. Voelkering and Charles Clingan of Burlington, Wis. He was purchased from them and arrived at Beltsville, June 20, 1944. The Voelkering herd had been in DHIA testing for about 8 years, and all cows were milked twice daily. The record books indicated stability and careful management, and all record information was readily available. The

cows were well cared for and fed according to good dairy farm practice.

The proof on which his selection was based was developed from the first records of 11 daughters, only 1 of which was milked in an outside herd. On a mature-equivalent, 305-day, two-times-daily milking basis, the proof was as follows:

Group	Average production		
	Milk	Butterfat	
	Pounds	*Percent*	*Pounds*
11 daughters	13, 377	3. 73	499
11 dams	12, 196	3. 78	459
Difference	+1, 181	−. 05	+40
Daughters better than dams—number	8	5	7

This information was then being supplemented by returns on 5 additional daughters and repeat records on some of the original 11, so that by the time he was established in service at Beltsville the proof had become:

Group	Average production		
	Milk	Butterfat	
	Pounds	*Percent*	*Pounds*
16 daughters	13, 750	3. 80	523
16 dams	12, 481	3. 81	475
Difference	+1, 269	−. 01	+48
Daughters better than dams—number	12	9	12

The records for this sire were more easily understood and interpreted than was true of some of the other sires because of the stability of management and care in seeing that the record books were maintained in a complete and orderly manner.

Experimental Results and Discussion

Distribution of Project Animals by Generation and Butterfat Production

Table 2 shows the number of animals in each generation sorted according to level of butterfat production. The total column at the right does not include the foundation group, as the system of breeding did not affect them. The average level of production increases steadily after the first generation. A 154-pound increase is shown for the first five generations and 24 pounds from the fifth to the eighth generation. There is some increase in variability up to the third generation and then, after a quick drop, a continued decline. The last three generations shown in the table are not complete because not all the daughters had been tested when this analysis was made. Means, standard deviations, and coefficients of variability are shown for each generation group.

TABLE 2.—*Animals in the foundation herd and in each proved-sire bred generation, grouped according to level of butterfat production*

Butterfat production level (pounds)	Foundation herd	Generation								
		1st	2d	3d	4th	5th	6th	7th	8th	Total
	Number	*Number*	*Number*	*Number*	*Number*	*Number*	*Number*	*Number*	*Number*	*Number*
900				1		2	2		1	6
850				1	1	1		1	2	6
800					8	8	3	3		22
750	1		2	3	8	9	15	7	5	49
700	1	1	2	5	13	11	17	13	4	66
650	1	2	5	11	12	16	16	4	7	73
600	3	8	6	9	9	9	9	5	4	59
550	1	3	4	7	10	9	4	2		39
500	4	11	6	4	8		4	2		35
450	1	5	3	3	2	1	1			15
400	4	4	5	3		1				13
350	1		1	2						3
300			1	1						2
250			1	1						2
200		1								1
Total	17	35	36	51	71	67	71	37	23	391
Sires—number		2	2	7	8	8	12	10	8	
Mean production—pounds	542	535	555	606	673	696	698	710	720	656
Standard deviation—do	113	98	121	134	99	99	85	77	87	
Coefficient of variation	21. 01	18. 37	21. 83	22. 18	14. 76	14. 26	12. 14	10. 80	12. 14	

The total bred herd of 391 females produced an average of 656 pounds of butterfat on a mature-equivalent, 305-day, twice-daily milking basis.

The material is presented graphically in figure 1, which affords a picture of the progress made and distribution of the animals in various levels of butterfat production.

Dam-and-Daughter Comparisons

The dam-daughter relation is shown in table 3. The 387 daughters averaged 655 pounds of butterfat and their dams 640 pounds; 211

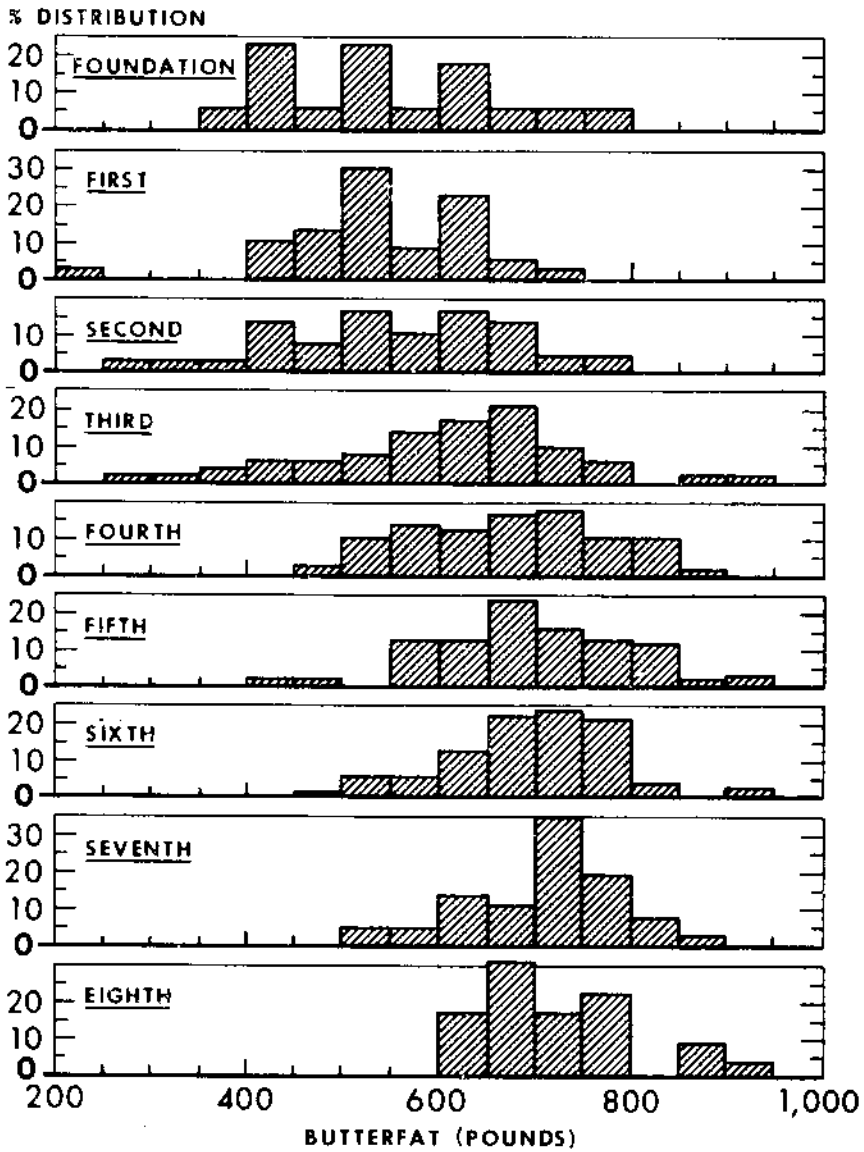

FIGURE 1.—Distribution of cows in various generations, by pounds of butterfat.

TABLE 3.—*Correlation of average butterfat yields of daughters and dams* [1]

Butterfat production class of dams (pounds)	Daughters in butterfat production class of—															
	900 Pounds	850 Pounds	800 Pounds	750 Pounds	700 Pounds	650 Pounds	600 Pounds	550 Pounds	500 Pounds	450 Pounds	400 Pounds	350 Pounds	300 Pounds	250 Pounds	200 Pounds	Total
	Number	Number	Number	Number	Number	Number	Number	Number	Number	Number	Number	Number	Number	Number	Number	
900	1					1										2
850			1	5		1										7
800			3	7	4	5	3									22
750	1		4	6	10	13	10		1	1				1		47
700	1	2	4	9	11	12	3	4	2				1		1	50
650		2	4	9	13	11	12	4	9			1				65
600	1	1	1	3	16	16	11	10	5	3	1	1	1			70
550	2		2	4	7	2	5	5	2		3					32
500			2	2	4	5	10	8	6	4	5			1		47
450			1	1		2	1	2	3	2	1					13
400				1	1	4	2	5	5	4	2					24
350									1							1
300				1			2			1						4
250									1			1				2
200											1					1
Total	6	5	22	48	66	72	59	38	35	15	13	3	2	2	1	387

[1] $r = 0.43$.

(54.5 percent) of the daughters produced more than their dams. Coefficient of correlation between daughters and dams was 0.43. Production records were not completed by the dams of 4 cows in the bred herd of 391.

Tables 4 and 5 show the relation between the production records of daughters when sorted according to the levels of production in each group.

Comparisons of the average butterfat production of the daughters produced in each generation with the records of their dams are shown in table 6. Only 15 percent of the daughters appeared in the same production category as their dams. The large negative difference between the foundation cows and their daughters calls for some explanation. The average of the 17 dams was 542 pounds of fat, but it happened that the 3 foundation cows with the highest records each produced 4 project daughters. Also, the lowest record (202 pounds of fat) was made by a daughter of one of these cows. This group of 12 daughters from 3 foundation cows averaged 575 pounds, which is 131 pounds less than their dams produced. The remaining 23 daughters of 14 dams averaged 514 pounds of fat, or 2 pounds above the level of their dams.

TABLE 4.—*Average butterfat production of dams and their daughters, grouped according to the level of butterfat production of the dams*

Butterfat production level of dams (pounds)	Comparisons	Average production		
		Dams	Daughters	Difference
	Number	*Pounds*	*Pounds*	*Pounds*
900–949	2	904	793	−111
850–899	7	877	769	−108
800–849	22	820	730	−90
750–799	47	773	688	−85
700–749	50	722	693	−29
650–699	65	671	674	+3
600–649	70	627	646	+19
550–599	32	577	664	+87
500–549	47	522	586	+64
450–499	13	481	588	+107
400–449	24	419	567	+148
350–399	1	377	534	+157
300–349	4	316	643	+327
250–299	2	282	445	+163
200–249	1	202	445	+243
Total or average	387	640	655	+15
Dams with butterfat production of—				
650 pounds or more	193	736	693	−43
Less than 650 pounds	194	544	617	+73

The effect of having so many daughters from the highest producing cows is to bring the weighted average of the dams to 578 pounds, or 36 pounds more than the unweighted average.

The daughters of the fifth-generation dams make up the only other group that averaged less than their dams, but the dams' level is higher than that of any other generation group.

TABLE 5.—*Average butterfat production of daughters and their dams, grouped according to the level of butterfat production of the daughters*

Butterfat production level of daughters (pounds)	Comparisons	Average production		
		Daughters	Dams	Difference
	Number	*Pounds*	*Pounds*	*Pounds*
900–949	6	918	697	+221
850–899	5	875	689	+186
800–849	22	817	700	+117
750–799	48	773	705	+68
700–749	66	723	672	+51
650–699	72	673	673	0
600–649	59	627	631	−4
550–599	38	574	577	−3
500–549	35	526	565	−39
450–499	15	477	509	−32
400–449	13	420	501	−81
350–399	3	375	529	−154
300–349	2	316	680	−364
250–299	2	271	636	−365
200–249	1	202	701	−499
Total or average	387	655	640	+15
Daughters with butterfat production of—				
650 pounds or more	219	736	683	+53
Less than 650 pounds	168	550	583	−33

Three-Generation Comparisons

The data included 355 3-generation comparisons. They originated from the foundation group to the sixth generation. The number and average butterfat production in the sequence from each generation are shown in table 7. The weighting of the high-producing cows in the foundation herd is again indicated in these figures. An arbitrary breakdown into two groups, one with original dams' records of 650 pounds of butterfat or more and the other all below 650 pounds, shows that in two generations the average decline from high-producing dams was 54 pounds, and the average increase from low-producing dams was 120 pounds.

TABLE 6.—*Two-generation comparison of average butterfat yields, grouped according to production of dams, by generation of origin*

Generation of origin	Comparisons	Dams	Daughters
	Dams produced 650 pounds or more		
	Number	*Pounds*	*Pounds*
Foundation	12	706	575
1st	1	680	367
2d	9	727	574
3d	34	710	690
4th	42	747	720
5th	51	753	705
6th	29	733	716
7th	15	743	729
Total or average	193	736	693
	Dams produced less than 650 pounds		
Foundation	23	512	514
1st	35	512	560
2d	42	513	613
3d	37	561	657
4th	24	592	658
5th	19	596	677
6th	8	557	691
7th	6	604	680
Total or average	194	544	617
	All dams		
Foundation	35	578	535
1st	36	517	555
2d	51	551	606
3d	71	633	673
4th	66	691	698
5th	70	711	697
6th	37	695	710
7th	21	703	715
Total or average	387	640	655

TABLE 7.—*Three-generation comparison of average butterfat yields, grouped according to production of original dams, by generation of origin*

Generation of origin	Comparisons	Generation 1	Generation 2	Generation 3
		Original dams produced 650 pounds or more		
	Number	*Pounds*	*Pounds*	*Pounds*
Foundation	14	710	548	542
1st	0			
2d	18	727	616	683
3d	34	709	692	663
4th	51	745	733	704
5th	28	755	708	704
6th	16	731	688	708
Total or average	161	733	686	679
		Original dams produced less than 650 pounds		
Foundation	22	482	497	563
1st	51	535	551	606
2d	53	519	638	669
3d	33	561	689	731
4th	19	577	658	676
5th	9	604	658	731
6th	7	571	736	747
Total or average	194	538	614	658
		All dams		
Foundation	36	571	517	555
1st	51	535	551	606
2d	71	571	633	673
3d	67	636	691	696
4th	70	700	712	697
5th	37	718	695	710
6th	23	682	704	720
Total or average	355	626	646	667

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Four-Generation Comparisons

Four-generation comparisons originated in all generations from the foundation to the fifth generation, inclusive. They number 319, and table 8 presents them in sequence from the generation of origin. Average butterfat production by the members of the fourth generation in each sequence was higher as the generation of origin progressed.

Fourth-generation descendants from high-producing original dams averaged only 14 pounds more butterfat than those from low-producing dams.

The three-generation decline from high-producing cows averaged 31 pounds, whereas the average three-generation increase from low-producing cows was 131 pounds.

TABLE 8.—*Four-generation comparison of average butterfat yields, grouped according to production of original dams, by generation of origin*

Generation of origin	Comparisons	Generation 1	Generation 2	Generation 3	Generation 4
	Original dams produced 650 pounds or more				
	Number	*Pounds*	*Pounds*	*Pounds*	*Pounds*
Foundation	27	722	574	570	606
1st	0				
2d	14	707	642	645	692
3d	37	688	687	704	718
4th	25	758	749	693	709
5th	16	739	693	675	727
Total or average	119	720	670	660	689
	Original dams produced less than 650 pounds				
Foundation	24	489	492	529	606
1st	71	544	571	633	673
2d	53	534	634	703	697
3d	34	576	714	714	675
4th	11	578	661	694	713
5th	7	584	657	760	703
Total or average	200	544	610	661	675
	All dams				
Foundation	51	612	535	551	606
1st	71	544	571	633	673
2d	67	570	636	691	696
3d	71	634	700	711	698
4th	36	703	722	693	710
5th	23	692	682	703	720
Total or average	319	609	633	661	680

Five-Generation Comparisons

Table 9 records the 269 five-generation sequences in accordance with the generation of their origin. The gain from the original dams to the members of the fifth generation averaged 100 pounds of butterfat.

The fifth-generation descendants from original dams that produced more than 650 pounds averaged only 11 pounds more than the fifth-generation progeny of original dams that produced less than 650 pounds. The original dam groups averaged 718 and 536 pounds, respectively.

The four-generation decline from high-producing dams was only 16 pounds, and the increase from low-producing dams averaged 155 pounds.

TABLE 9.—*Five-generation comparison of average butterfat yields, grouped according to production of original dams, by generation of origin*

Generation of origin	Comparisons	Generation 1	Generation 2	Generation 3	Generation 4	Generation 5
	Original dams produced 650 pounds or more					
	Number	*Pounds*	*Pounds*	*Pounds*	*Pounds*	*Pounds*
Foundation	41	727	590	588	638	687
1st	0					
2d	17	712	670	661	695	692
3d	15	680	681	727	736	725
4th	13	739	733	696	688	734
Total or average	86	718	644	643	674	702
	Original dams produced less than 650 pounds					
Foundation	30	483	482	548	625	654
1st	67	533	570	636	691	696
2d	54	537	623	712	716	700
3d	22	574	719	713	668	701
4th	10	620	639	644	724	704
Total or average	183	536	592	655	682	691
	All dams					
Foundation	71	624	544	571	633	673
1st	67	533	570	636	691	696
2d	71	579	634	700	711	698
3d	37	617	703	718	695	710
4th	23	687	692	682	703	720
Total or average	269	594	609	651	682	694

Six-Generation Comparisons

The six-generation sequences number 198, and they stem from original dams in the foundation herd and from first-, second-, and third-generation cows. They are arranged according to generation of origin in table 10. The improvement in average production from original dams to members of the sixth generation was 129 pounds of fat.

The sixth-generation descendants of the original group of high-producing dams (over 650 pounds of fat) averaged 13 pounds more fat than those of the low-producing dams, but the average of the original high-producing dams was 200 pounds higher than that of the original dams that produced less than 650 pounds.

The decline in the group descended from high-producing dams averaged 12 pounds of fat, and the increase in the group descended from low-producing dams was 175 pounds.

TABLE 10.—*Six-generation comparison of average butterfat yields, grouped according to production of original dams, by generation of origin*

Generation of origin	Comparisons	Generation 1	2	3	4	5	6
	Original dams produced 650 pounds or more						
	Number	*Pounds*	*Pounds*	*Pounds*	*Pounds*	*Pounds*	*Pounds*
Foundation	33	728	581	591	656	734	710
1st	0						
2d	6	753	659	577	703	721	740
3d	9	691	706	737	729	677	700
Total or average	48	724	614	617	676	724	712
	Original dams produced less than 650 pounds						
Foundation	34	472	486	550	616	647	682
1st	71	533	579	634	700	711	698
2d	31	546	609	729	722	691	705
3d	14	559	676	663	652	716	732
Total or average	150	524	573	637	681	693	699
	All dams						
Foundation	67	598	533	570	636	691	696
1st	71	533	579	634	700	711	698
2d	37	580	617	706	718	695	710
3d	23	611	687	692	682	703	720
Total or average	198	573	583	632	680	700	702

Seven-Generation Comparisons

The data provided 131 seven-generation sequences from original dams in the foundation and first- and second-generation groups. Table 11 has these sequences arranged according to generation of origin. The members of the seventh generation averaged 135 pounds more fat than the original dams from which they were descended.

Descendants in the seventh generation from the original group of low-producing dams averaged 7 pounds more fat than those from the high-producing dams, but the original high-producing dams averaged 217 pounds more than the other group.

TABLE 11.—*Seven-generation comparison of average butterfat yields, grouped according to production of original dams, by generation of origin*

Generation of origin	Comparisons	Generation						
		1	2	3	4	5	6	7
	Number	*Pounds*	*Pounds*	*Pounds*	*Pounds*	*Pounds*	*Pounds*	*Pounds*
Original dams produced 650 pounds or more								
Foundation	35	726	578	576	633	745	735	704
1st	0							
2d	3	701	655	641	763	727	665	659
Total or average	38	724	584	581	644	743	729	700
Original dams produced less than 650 pounds								
Foundation	36	469	488	581	635	655	686	692
1st	37	550	580	617	703	718	695	710
2d	20	495	604	694	681	676	710	739
Total or average	93	507	549	620	672	685	695	707
All dams								
Foundation	71	595	533	579	634	700	711	698
1st	37	550	580	617	703	718	695	710
2d	23	522	611	687	692	682	703	720
Total or average	131	570	560	609	664	702	705	705

Eight- and Nine-Generation Comparisons

All 60 of these sequences originated in the foundation and first-generation groups. Table 12 shows all of the eight-generation sequences.

Table 13 lists the nine-generation sequences from dams whose production was above and below 650 pounds of fat.

TABLE 12.—*Eight-generation comparison of average butterfat yields, grouped according to production of original dams, by generation of origin*

Generation of origin	Comparisons	Generation							
		1	2	3	4	5	6	7	8
	Original dams produced 650 pounds or more								
	Number	*Pounds*	*Pounds*	*Pounds*	*Pounds*	*Pounds*	*Pounds*	*Pounds*	*Pounds*
Foundation	22	739	581	589	614	651	740	685	698
1st	0								
Total or average	22	739	581	589	614	651	740	685	698
	Original dams produced less than 650 pounds								
Foundation	12	512	510	577	614	620	679	711	734
1st	26	523	518	601	683	688	686	704	714
Total or average	38	520	516	593	661	668	684	706	723
	All dams								
Foundation	37	638	550	580	617	703	718	695	710
1st	23	539	522	611	687	692	682	703	720
Total or average	60	600	540	592	644	699	705	698	714

TABLE 13.—*Nine-generation comparison of average butterfat yields, grouped according to production of original dams, by generation of origin*

Generation of origin	Comparisons	Generation								
		1	2	3	4	5	6	7	8	9
	Original dams produced 650 pounds or more									
	Number	*Pounds*	*Pounds*	*Pounds*	*Pounds*	*Pounds*	*Pounds*	*Pounds*	*Pounds*	*Pounds*
Foundation	11	728	572	570	620	740	726	695	683	742
	Original dams produced less than 650 pounds									
Foundation	12	476	509	478	602	639	661	670	722	699
	All dams									
Foundation	23	597	539	522	611	687	692	682	703	720

As a final summary, table 14 was compiled to show the average records of the original dams from which each sequence of two to nine generations is descended, and the average production of the descendants in the final generation. The data are shown in total and when sorted on a basis of original dams that produced more or less than 650 pounds of fat.

TABLE 14.—SUMMARY: *Average butterfat yields of the original dams and their descendants in each generation*

Generations in sequence (number)	Comparisons	Dams	Descendants	Difference
	Original dams produced 650 pounds or more			
	Number	*Pounds*	*Pounds*	*Pounds*
2	193	736	693	−46
3	161	733	679	−54
4	119	720	689	−31
5	86	718	702	−16
6	48	724	712	−12
7	38	724	700	−24
8	22	739	698	−41
9	11	723	742	+14
	Original dams produced less than 650 pounds			
2	194	544	617	+73
3	194	538	658	+120
4	199	544	675	+131
5	183	536	691	+155
6	150	524	699	+175
7	93	507	707	+200
8	38	520	723	+203
9	12	476	699	+223
	All dams			
2	387	640	655	+15
3	355	626	667	+41
4	319	609	680	+71
5	269	594	694	+100
6	198	573	702	+129
7	131	570	705	+135
8	60	600	714	+114
9	23	597	720	+123

Levels of Butterfat Production

This report presents the effect of a system of breeding dairy cattle on the level of butterfat production. Results already noted indicate a fairly steady increase in butterfat production by generations, and it is interesting to look at the project animals when grouped according to the level of their own performance. This is offered in the hope that it will afford some explanation of relation of individual merit to transmitting ability.

The project animals were originally studied in groups with a production range of 50 pounds of butterfat, but in order to conserve space these groups were further consolidated.

The material is presented in a series of tables and figures designed to show the dam-and-daughter relationships of cows on different levels of butterfat production and also the effects on these relationships wrought by successive generations of proved-sire breeding.

Breeders are always interested in the origin and transmitting potential of the better producing cows. However, these tables offer such information not only on the better cows but on an entire herd. For instance, daughters that produced 900, 800, and 700 pounds of butterfat were all from dams that averaged close to 700 pounds; but daughters that produced 600, 500, and 400 pounds were from dams that averaged 654, 571, and 505 pounds, respectively. On the other hand, dams that produced 900, 800, 700, 600, 500, and 400 pounds had daughters that averaged 793, 739, 690, 660, 618, and 574 pounds, respectively.

Table 18, which deals with the 600-pound butterfat level, shows that sixty-two 600-pound cows born in the first, second, third, and fourth generation were from dams that averaged 598 pounds, while the 69 born in the fifth, sixth, seventh, and eighth generations had dams that averaged 705 pounds—a 49-pound increase in the early generations and a 48-pound decrease in the last four generations. There is also the interesting observation that the 600-pound cows in the foundation group and first, second, and third generations had 67 daughters that averaged 642 pounds, which was the same as the average of their dams; whereas 600-pound cows in the fourth, fifth, sixth, and seventh generations had 68 daughters that averaged 677 pounds of butterfat, or 22 pounds more than their dams. Similar data are given for other levels of production.

The tabular material indicates the number of tested cows of different production levels that appeared in each generation, the number that had tested daughters, and the number of tested daughters. In addition, the average butterfat production of each group of dams and daughters and the difference between daughters and dams is shown. After the figures for the entire group there is a breakdown into subgroups, one made up of the first four generations and the other the last four generations.

While the average production of dams and daughters of cows of different levels of production is important, these averages acquire additional interest when the range of production is added. This is shown graphically in figures 2 and 3.

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TABLE 15.—*Cows that produced over 900 pounds of butterfat*

Generation in which they appeared	Comparisons	Average production			900-pound cows that had daughters	Tested daughters	Average production		
		900-pound cows	Dams of 900-pound cows	Difference			Daughters	900-pound dams	Difference
	Number	*Pounds*	*Pounds*	*Pounds*	*Number*	*Number*	*Pounds*	*Pounds*	*Pounds*
Foundation	0								
1st	0								
2d	0								
3d	1	966	638	+328	0				
4th	0								
5th	2	907	644	+263	1	2	793	904	−111
6th	2	906	728	+178	2				
7th	0								
8th	1	917	799	+118	1				
Total or average	6	918	697	+221	4	2	793	904	−111

TABLE 16.—*Cows that produced 800 to 899 pounds of butterfat*

Generation in which they appeared	Comparisons	Average production			800-pound cows that had daughters	Tested daughters	Average production		
		800-pound cows	Dams of 800-pound cows	Difference			Daughters	800-pound dams	Difference
	Number	*Pounds*	*Pounds*	*Pounds*	*Number*	*Number*	*Pounds*	*Pounds*	*Pounds*
Foundation	0								
1st	0								
2d	0								
3d	1	882	626	+256	1	3	793	882	−89
4th	9	827	651	+176	7	11	753	835	−82
5th	9	828	740	+88	8	12	710	827	−117
6th	3	809	731	+78	1	1	774	820	−46
7th	4	809	672	+137	4	2	738	805	−67
8th	1	875	720	+155	2				
Total or average	27	828	698	+130	23	29	739	834	−95

Group	Comparisons	Average production		
		Daughters	Dams	Difference
	Number	*Pounds*	*Pounds*	*Pounds*
800-pound daughters born in—				
3d and 4th generations	10	832	659	+173
5th, 6th, 7th, and 8th generations	17	825	721	+104
800-pound dams in—				
3d generation	3	793	882	−89
4th, 5th, 6th, and 7th generations	26	733	829	−104

TABLE 17.—*Cows that produced 700 to 799 pounds of butterfat*

Generation in which they appeared	Comparisons	Average production			700-pound cows that had daughters	Tested daughters	Average production		
		700-pound cows	Dams of 700-pound cows	Difference			Daughters	700-pound dams	Difference
	Number	*Pounds*	*Pounds*	*Pounds*	*Number*	*Number*	*Pounds*	*Pounds*	*Pounds*
Foundation	2	733			2	8	561	733	−172
1st	1	704	652	+52	0				
2d	4	748	560	+188	4	7	550	744	−184
3d	8	743	594	+149	7	12	692	743	−51
4th	21	742	651	+91	16	18	729	745	−16
5th	20	746	700	+46	18	22	716	754	−38
6th	31	747	717	+30	29	21	701	746	−45
7th	20	742	708	+34	19	9	751	753	−2
8th	9	749	723	+26	9				
Total or average	114	745	686	+59	104	97	690	747	−57

Group	Comparisons	Average production		
		Daughters	Dams	Difference
	Number	*Pounds*	*Pounds*	*Pounds*
700-pound daughters born in—				
1st, 2d, 3d, and 4th generations	34	742	630	+112
5th, 6th, 7th, and 8th generations	80	746	711	+35
700-pound dams in—				
Foundation, 1st, 2d, and 3d generations	27	616	740	−124
4th, 5th, 6th, and 7th generations	70	719	749	−30

TABLE 18.—*Cows that produced 600 to 699 pounds of butterfat*

Generation in which they appeared	Comparisons	Average production			600-pound cows that had daughters	Tested daughters	Average production		
		600-pound cows	Dams of 600-pound cows	Difference			Daughters	600-pound dams	Difference
	Number	*Pounds*	*Pounds*	*Pounds*	*Number*	*Number*	*Pounds*	*Pounds*	*Pounds*
Foundation	4	638			4	8	573	643	−70
1st	10	634	657	−23	7	8	583	635	−52
2d	11	641	548	+93	9	17	666	626	+40
3d	20	650	550	+100	17	34	660	651	+9
4th	21	654	641	+13	19	24	664	657	+7
5th	25	656	690	−34	22	26	662	650	+12
6th	25	661	729	−68	21	10	741	664	+77
7th	9	658	712	−54	9	8	681	655	+26
8th	10	648	675	−27	8				
Total or average	131	652	654	−2	116	135	660	648	+12

Group	Comparisons	Average production		
		Daughters	Dams	Difference
	Number	*Pounds*	*Pounds*	*Pounds*
600-pound daughters born in—				
1st, 2d, 3d, and 4th generations	62	647	598	+49
5th, 6th, 7th, and 8th generations	69	657	705	−48
600-pound dams in—				
Foundation, 1st, 2d, and 3d, generations	67	642	642	0
4th, 5th, 6th, and 7th generations	68	677	655	+22

TABLE 19.—*Cows that produced 500 to 599 pounds of butterfat*

Generation in which they appeared	Comparisons	Average production			500-pound cows that had daughters	Tested daughters	Average production		
		500-pound cows	Dams of 500-pound cows	Difference			Daughters	500-pound dams	Difference
	Number	*Pounds*	*Pounds*	*Pounds*	*Number*	*Number*	*Pounds*	*Pounds*	*Pounds*
Foundation	5	531			5	11	513	530	−17
1st	14	530	552	−22	11	16	557	522	+35
2d	10	544	491	+53	8	11	570	539	+31
3d	11	550	508	+42	9	14	671	561	+110
4th	18	559	597	−38	14	13	669	555	+114
5th	8	571	646	−75	7	8	715	566	+149
6th	8	553	630	−77	6	4	707	535	+172
7th	4	560	618	−58	4	2	666	571	+95
8th	0								
Total or average	73	551	571	−20	64	79	618	544	+74

Group	Comparisons	Average production		
		Daughters	Dams	Difference
	Number	*Pounds*	*Pounds*	*Pounds*
500-pound daughters born in—				
1st, 2d, 3d, and 4th generations	53	547	547	0
5th, 6th, and 7th generations	20	562	637	−75
500-pound dams in—				
Foundation, 1st, 2d, and 3d generations	52	581	538	+43
4th, 5th, 6th, and 7th generations	27	688	556	+132

TABLE 20.—*Cows that produced 400 to 499 pounds of butterfat*

Generation in which they appeared	Comparisons	Average production			400-pound cows that had daughters	Tested daughters	Average production		
		400-pound cows	Dams of 400-pound cows	Difference			Daughters	400-pound dams	Difference
	Number	*Pounds*	*Pounds*	*Pounds*	*Number*	*Number*	*Pounds*	*Pounds*	*Pounds*
Foundation	5	434			5	7	497	434	+63
1st	9	450	511	−61	8	11	541	451	+90
2d	8	443	450	−7	6	12	621	426	+195
3d	6	457	514	−57	6	6	575	440	+135
4th	2	471	525	−54	0				
5th	2	441	598	−157	0				
6th	1	455	616	−151	1	1	556	455	+101
7th and 8th	0								
Total or average	28	451	505	−54	25	37	574	441	+133

Group	Comparisons	Average production		
		Daughters	Dams	Difference
	Number	*Pounds*	*Pounds*	*Pounds*
400-pound daughters born in—				
1st, 2d, 3d, and 4th generations	25	451	493	−42
5th and 6th generations	3	445	604	−159
400-pound dams in—				
Foundation, 1st, 2d, and 3d generations	36	575	440	+135
6th generation	1	556	455	+101

TABLE 21.—*Cows that produced less than 400 pounds of butterfat*

Generation in which they appeared	Comparisons	Average production			Under 400-pound cows that had daughters	Tested daughters	Average production		
		Under 400-pound cows	Dams of under 400-pound cows	Difference			Daughters	Under 400-pound dams	Difference
	Number	*Pounds*	*Pounds*	*Pounds*	*Number*	*Number*	*Pounds*	*Pounds*	*Pounds*
Foundation	1	377			1	1	534	377	+157
1st	1	202	701	−499	1	1	445	202	+243
2d	3	321	611	−290	2	4	506	298	+208
3d	4	334	596	−262	1	2	719	318	+401
4th to 8th	0								
Total or average [1]	8	312	617	−305	5	8	555	301	+254

[1] Foundation group omitted.

Figures 2 and 3 are based on a division of the data into below-average and above-average groups, with 650 pounds of butterfat as the division point. The dams of 219 cows that produced 650 pounds or more ranged from 300 to 900 pounds, and averaged 683 pounds. The 193 daughters of cows that produced over 650 pounds ranged from 200 to 900 pounds, and averaged 693 pounds.

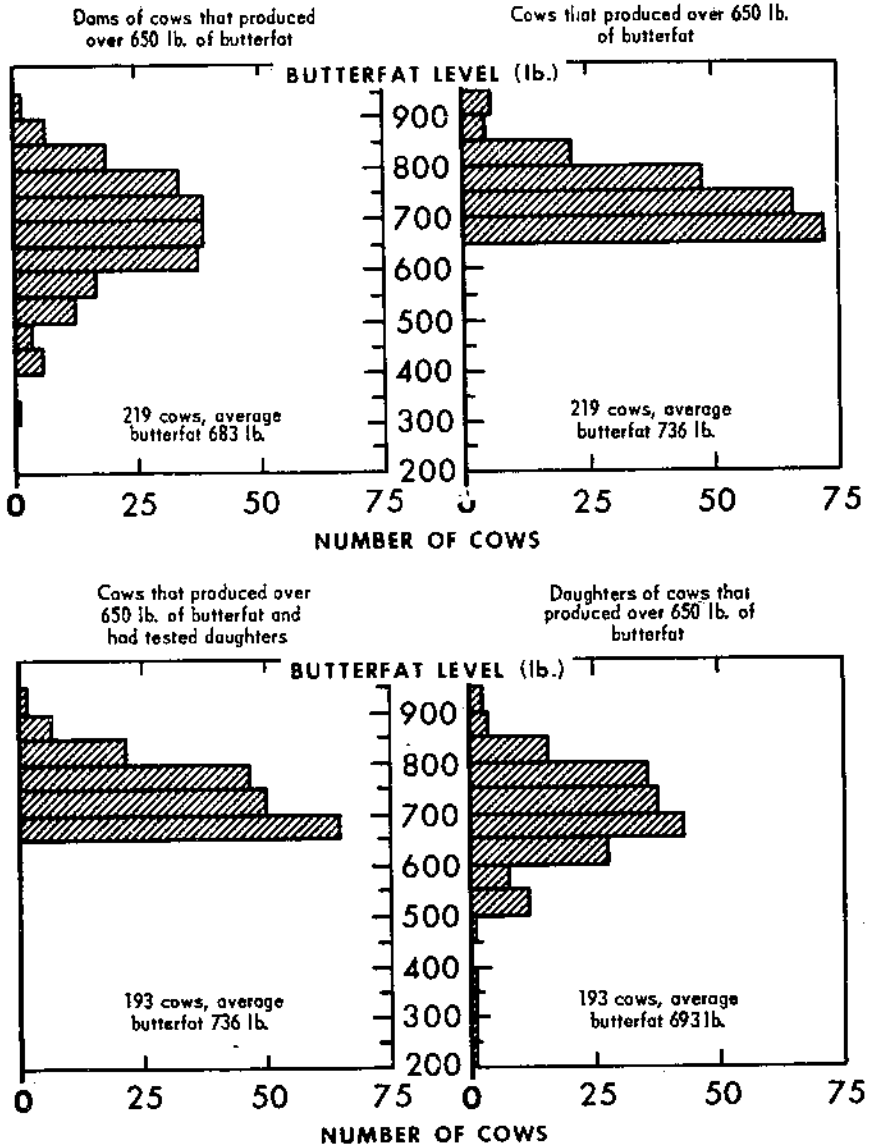

FIGURE 2.—Butterfat level of cows that produced 650 pounds or more as compared with that of their dams and of their daughters.

The dams of 168 cows that produced less than 650 pounds ranged from 200 to 800 pounds, and averaged 583 pounds. The 194 daughters of cows that produced less than 650 pounds ranged from 300 to 900, and averaged 617 pounds. Six cows produced more than 900 pounds, and half of them were from dams that produced less than 650 pounds.

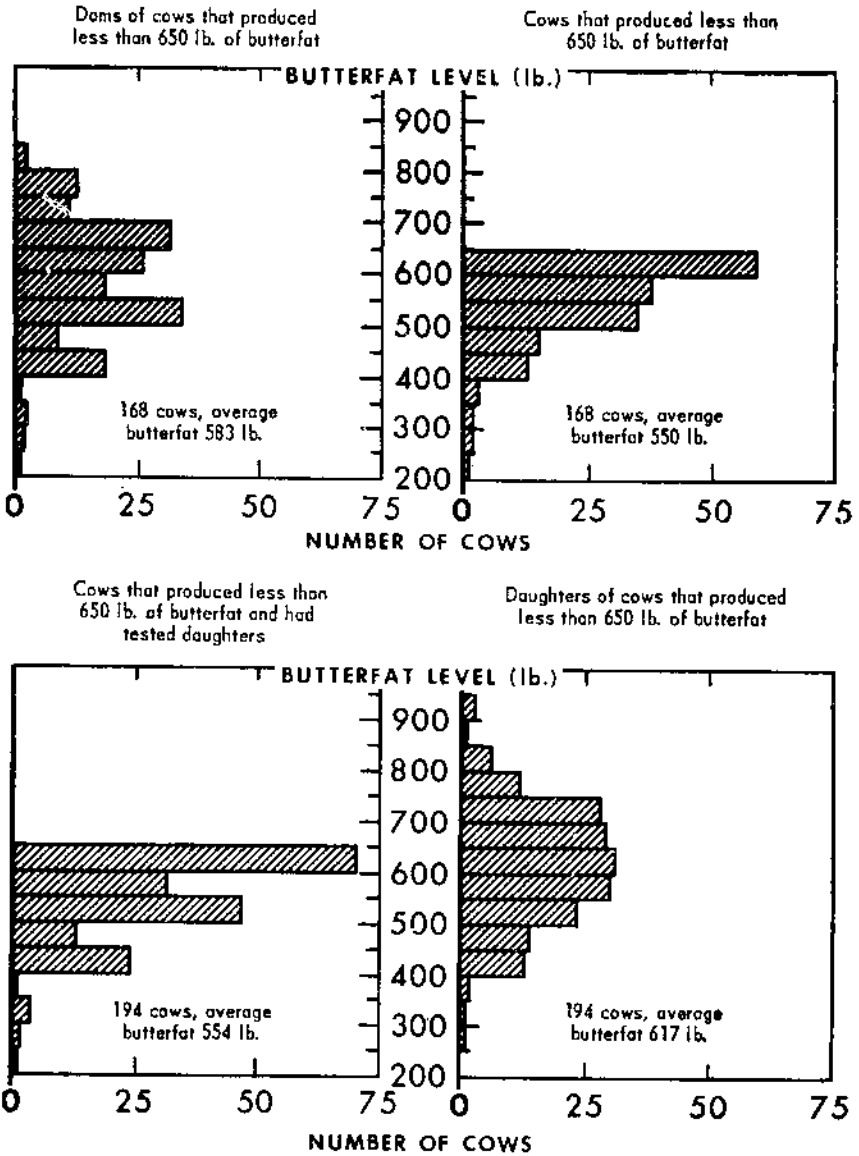

FIGURE 3.—Butterfat level of cows that produced less than 650 pounds as compared with that of their dams and of their daughters.

A Study of the Effects of Female Selection

A general recommendation to dairymen and breeders has been not to raise any daughters from the lower producing cows in their herds. Fortunately for those making the recommendation, there is no accurate way for dairymen who follow this advice to determine the effectiveness of this type of selection. If daughters from lower producing cows are not raised, they do not become part of the herd, their production records are not available, and they in turn make no contribution to the future herd or the analysis. However, the breeding experiment with Holstein cattle reported here was conducted without culling daughters of any cow regardless of the dam's production. As a consequence, the data represent a complete herd, which makes it possible to determine accurately what the results would have been if such a policy of selection had been incorporated in the experimental procedure from the beginning.

First the data were analyzed to determine the results of discarding daughters of all cows that produced less than 400 pounds of butterfat. With an initial average of close to 550 pounds, this did not appear to be extreme, and as a matter of fact, only nine cows in the herd produced less than 400 pounds. One was a foundation cow, one appeared in the first generation, and three in the second generation; all but one of these five had female progeny. The other four came in the third generation, and they include the two abnormal daughters of Sire No. 3 and two inbreds. The only contribution from these four came from one of the abnormals. The other abnormal had only male offspring, and the two inbreds also had no female offspring. In the selection we were concerned only with the progeny of five cows, and the total population of the foundation herd and first three generations totaled 139, so the proportion of those involved was very small. The level of selection of 400 pounds is modest in a herd of this kind.

In looking at the results in table 22, it is well to remember that when a daughter of a dam that produced less than 400 pounds is discarded, the herd also loses all her future descendants, and these too constitute a gain or loss to the future herd. The upper part of table 22 shows the effect on average butterfat production and the lower half indicates the change in numbers by generation and production level. The information in the table is on a generation basis in order to conform to material previously presented.

The column "Discarded herd" is made up of the animals in each generation that had at least one female ancestor that produced less than 400 pounds of fat. The 37 in this category are the animals that would not have appeared in the herd. Their average was 631 pounds of butterfat, and by omitting them the residual herd of 354 females averaged 2 pounds more than the herd with all progeny raised.

The results at the 400-pound level were interesting, and it was determined to try the effect of raising the level of selection to 410 pounds of butterfat and again to 420 pounds. At the 410-pound level, the "raised" herd of 299 cows averaged 659 pounds of butterfat and the "discarded" group of 92 averaged 645. When the level was set at 420, the "raised" herd of 266 averaged 660 pounds of fat and the "discarded" group of 125 averaged 647.

TABLE 22.—*Effect on herd if all daughters of cows that produced less than 400 pounds of butterfat had been discarded*

EFFECT ON PRODUCTION

Generation	Whole herd		"Raised" herd		"Discarded" herd	
	Number	Average production	Number	Average production	Number	Average production
		Pounds		*Pounds*		*Pounds*
1st	35	535	34	535	1	534
2d	36	555	34	555	2	555
3d	51	606	45	613	6	558
4th	71	673	62	677	9	645
5th	67	696	59	702	8	658
6th	71	698	63	701	8	672
7th	37	710	36	713	1	606
8th	23	720	21	726	2	649
Total or average	391	656	354	658	37	631

EFFECT ON NUMBERS IN VARIOUS LEVEL-OF-PRODUCTION GROUPS

[First number in each column indicates all cows; second number, those that would have been discarded]

Generation	Butterfat production level								
	900 pounds	800 pounds	700 pounds	600 pounds	500 pounds	400 pounds	300 pounds	200 pounds	All groups
	Number	*Number*	*Number*	*Number*	*Number*	*Number*	*Number*	*Number*	*Number*
1st	----------	----------	1–0	10– 0	14–1	9–0	----------	1–0	35– 1
2d	----------	----------	4–0	11– 1	10–0	8–1	2–0	1–0	36– 2
3d	1–0	1–0	8–0	20– 3	11–1	6–1	3–1	1–0	51– 6
4th	----------	9–0	21–3	21– 2	18–4	2–0	----------	----------	71– 9
5th	2–0	9–1	20–2	25– 3	9–1	2–1	----------	----------	67– 8
6th	2–0	3–0	32–3	25– 3	8–2	1–0	----------	----------	71– 8
7th	----------	4–0	20–0	9– 1	4–0	----------	----------	----------	37– 1
8th	1–0	2–0	9–0	11– 2	----------	----------	----------	----------	23– 2
Total	6–0	28–1	115–8	132–15	74–9	28–3	5–1	3–0	391–37

Up to this point it would appear that as the selection level was raised by 10 pounds of fat, the residual herd averaged 1 pound more. The selection level and number of cows did not appear to be out of proportion to the average of the herd and total number of cows.

The next step up in the selection level was only 5 pounds, which set it at 425 pounds of fat.

The effects of this procedure on average butterfat production and numbers of animals are shown in table 23.

The total number of cows with records of less than 425 pounds of butterfat was 21, with 4 in the foundation herd, 4 in the first generation, 7 in the second, and 6 in the third. Fifteen involved in the selection procedure included 4 foundation cows, 3 in the first generation, 5 in the second, and 3 in the third. Including the fourth generation these 15 had 82 female progeny, of which 4 produced less than 425 pounds of fat; the remaining 118 cows had 13 below that figure in a total of 111. The results were rather startling when it was found that the 176 cows in the "discarded" herd averaged 661 pounds of fat, or 10 pounds more than the 215 that would have been raised. It is interesting to observe that the selection procedure at this level resulted in a loss of about half the animals in the third, fourth, fifth, and sixth generations. The last two generations are not complete. Seventeen cows in the "raised" herd produced less than 425 pounds of fat, and only four of these had a female ancestor that failed to reach or exceed that level.

Table 23 also shows the percentage of females that would have been raised with selection based on 425 pounds of fat. For the whole herd of 391 cows, 55 percent would have been raised. This basis of selection affected all levels of production from 400 pounds and more about equally, and these levels include over 98 percent of all animals in the study. In the combined 800- and 900-pound groups, 53 percent were in the raised group. This figure, along with the percentage shown in the last column, shows that the effect by generations, beginning with the third, and by levels of production, tends to be fairly uniform. This type of selection failed to exclude from the herd the lowest producing animals.

If no daughters of cows that produce less than 425 pounds of butterfat were to be raised, theoretically we would have two herds —one would be the "raised" herd and the other the "discarded" herd. These two herds are defined by generations and levels of production in tables 24 and 25, to afford a better understanding of what would have taken place.

The data show the ineffectiveness of heifer selection based on the dam's low level of butterfat production. The complete data have made it possible to establish the total gain or loss to the future herd that would have been brought about by this type of selection. No doubt the results shown here are in part due to the influence of the sires used to produce the herd.

The old genetic theory that like begets like may be the basis of the recommended practice of culling heifers from low-producing dams. Its continued use would certainly not be harmful, but it appears that its possibilities have been overemphasized for greatly improving the production level of the herd.

TABLE 23.—*Effect on herd if all daughters of cows that produced less than 425 pounds of butterfat had been discarded*

EFFECT ON PRODUCTION

Generation	Whole herd		"Raised" herd		"Discarded" herd		Percentage raised
	Number	Average production	Number	Average production	Number	Average production	
		Pounds		*Pounds*		*Pounds*	*Percent*
1st	35	535	30	544	5	482	86
2d	36	555	24	556	12	553	67
3d	51	606	27	605	24	607	53
4th	71	673	35	683	36	663	49
5th	67	696	32	718	35	676	48
6th	71	698	34	696	37	700	48
7th	37	710	24	706	13	718	65
8th	23	720	9	731	14	712	39
Total or average	391	656	215	651	176	661	55

TABLE 23.—*Effect on herd if all daughters of cows that produced less than 425 pounds of butterfat had been discarded*—Continued

EFFECT ON NUMBERS IN VARIOUS LEVEL-OF-PRODUCTION GROUPS

[First number in each column indicates all cows; second number, those that have been discarded]

Generation	Butterfat production level									Percentage raised
	900 pounds	800 pounds	700 pounds	600 pounds	500 pounds	400 pounds	300 pounds	200 pounds	Total	
	Number	*Number*	*Number*	*Number*	*Number*	*Number*	*Number*	*Number*	*Number*	*Percent*
1st	-------	-------	1– 0	10– 0	14– 2	9– 3	-------	1–0	35– 5	86
2d	-------	-------	4– 1	11– 3	10– 4	8– 4	2–0	1–0	36– 12	67
3d	1–0	1–0	8– 5	20– 9	11– 6	6– 3	3–1	1–0	51– 24	53
4th	-------	9–4	21–10	21–11	18–10	2– 1	-------	-------	71– 36	49
5th	2–2	9–3	20–10	25–12	9– 6	2– 2	-------	-------	67– 35	48
6th	2–2	3–2	32–13	25–15	8– 5	1– 0	-------	-------	71– 37	48
7th	-------	4–1	20– 8	9– 4	4– 0	-------	-------	-------	37– 13	65
8th	1–1	2–1	9– 5	11– 7	-------	-------	-------	-------	23– 14	39
Total	6–5	28–11	115–52	132–61	74–33	28–13	5–1	3–0	391–176	-------
	Percent	*Percent*	*Percent*	*Percent*	*Percent*	*Percent*	*Percent*	*Percent*		*Percent*
Percentage raised	17	61	55	54	55	55	80	100	-------	55

TABLE 24.—*Distribution of the "raised" herd at a selection level of 425 pounds of butterfat*

Butterfat production class (pounds)	Generation								
	1st	2d	3d	4th	5th	6th	7th	8th	Total
	Number	*Number*	*Number*	*Number*	*Number*	*Number*	*Number*	*Number*	*Number*
900			1						1
850			1	1	1		1	1	5
800				4	5	1	2		12
750		2		5	6	8	4	2	27
700	1	1	3	6	4	11	8	2	36
650	2	3	5	9	9	6	3	4	41
600	8	5	6	1	4	4	2		30
550	3	3	5	3	3	2	2		21
500	9	3		5		1	2		20
450	3	1	2	1		1			8
400	3	3	1						7
350		1	1						2
300		1	1						2
250		1	1						2
200	1								1
Total	30	24	27	35	32	34	24	9	215
Average	*Pounds* 544	*Pounds* 556	*Pounds* 605	*Pounds* 683	*Pounds* 718	*Pounds* 696	*Pounds* 706	*Pounds* 731	*Pounds* 651

TABLE 25.—*Distribution of the "discarded" herd at a selection level of 425 pounds of butterfat*

Butterfat production class (pounds)	Generation								
	1st	2d	3d	4th	5th	6th	7th	8th	Total
	Number	*Number*	*Number*	*Number*	*Number*	*Number*	*Number*	*Number*	*Number*
900					2	2		1	5
850								1	1
800				4	3	2	1		10
750			3	3	3	7	3	3	22
700		1	2	7	7	6	5	2	30
650		2	6	3	7	10	1	3	32
600		1	3	8	5	5	3	4	29
550		1	2	7	6	2			18
500	2	3	4	3		3			15
450	2	2	1	1	1				7
400	1	2	2		1				6
350			1						1
300									
250									
200									
Total	5	12	24	36	35	37	13	14	176
Average production	*Pounds* 482	*Pounds* 553	*Pounds* 607	*Pounds* 663	*Pounds* 676	*Pounds* 700	*Pounds* 718	*Pounds* 712	*Pounds* 661

This type of female selection should not be confused with the practice of culling low-producing cows for management purposes. The latter has an immediate beneficial effect on the herd average and on the economy of operating a dairy herd. However, when production-proved sires are used, there appears to be very little benefit, so far as herd improvement is concerned, in discarding the daughters of the lower producing cows. Perhaps better advice to dairymen would be to sell these cows but raise their daughters, if the daughters are sired by production-proved bulls.

Since the evidence submitted reveals the effect or lack of effect of female selection, it might be interesting to further explore the data to try to determine the impact of selection on succeeding generations, and how soon its effect is lost. Table 26 was prepared to show the comparative progress by generations of descendants of the cows that had records below 425 pounds of butterfat and descendants of the rest of the cows.

TABLE 26.—*Average butterfat production, by generations, of descendants of cows grouped according to production class*

Production class [1]	Comparisons	Dams	Generation							
			1st	2d	3d	4th	5th	6th	7th	8th
	Number	*Pounds*	*Pounds*	*Pounds*	*Pounds*	*Pounds*	*Pounds*	*Pounds*	*Pounds*	*Pounds*
A	28	382	562							
B	359	660	662							
C	387	640	655							
A	33	383	570	635						
B	322	650	654	671						
C	355	626	646	667						
A	30	412	593	639	677					
B	289	630	637	663	680					
C	319	609	633	661	680					
A	35	410	575	617	689	686				
B	234	621	614	656	681	696				
C	269	594	609	651	682	694				
A	31	405	573	617	684	665	694			
B	167	604	585	635	679	707	704			
C	198	573	583	632	680	700	702			
A	29	402	544	612	660	658	709	704		
B	102	618	564	608	665	714	704	705		
C	131	570	560	609	664	702	705	705		
A	3	402	489	526	649	659	717	711	675	
B	57	610	542	595	644	701	704	697	716	
C	60	600	540	592	644	699	705	698	714	
A	3	387	517	583	648	637	688	670	619	667
B	20	628	543	513	605	695	693	684	717	727
C	23	597	539	522	611	687	692	682	703	720

[1] A=Cows that produced less than 425 pounds of butterfat.
B=Cows that produced more than 425 pounds of butterfat.
C=All cows.

The large increases made by daughters of the low-producing cows in most groups place them close to the level of the daughters of the other cows. Usually in two generations the progeny of low-producing cows are about equal in ability to those of the rest of the group, and from then on there is little to choose between descendants of either group of cows.

These changes in the differences between descendants of cows arbitrarily grouped according to their levels of production are more easily grasped when studied graphically, and figures 4 and 5 were

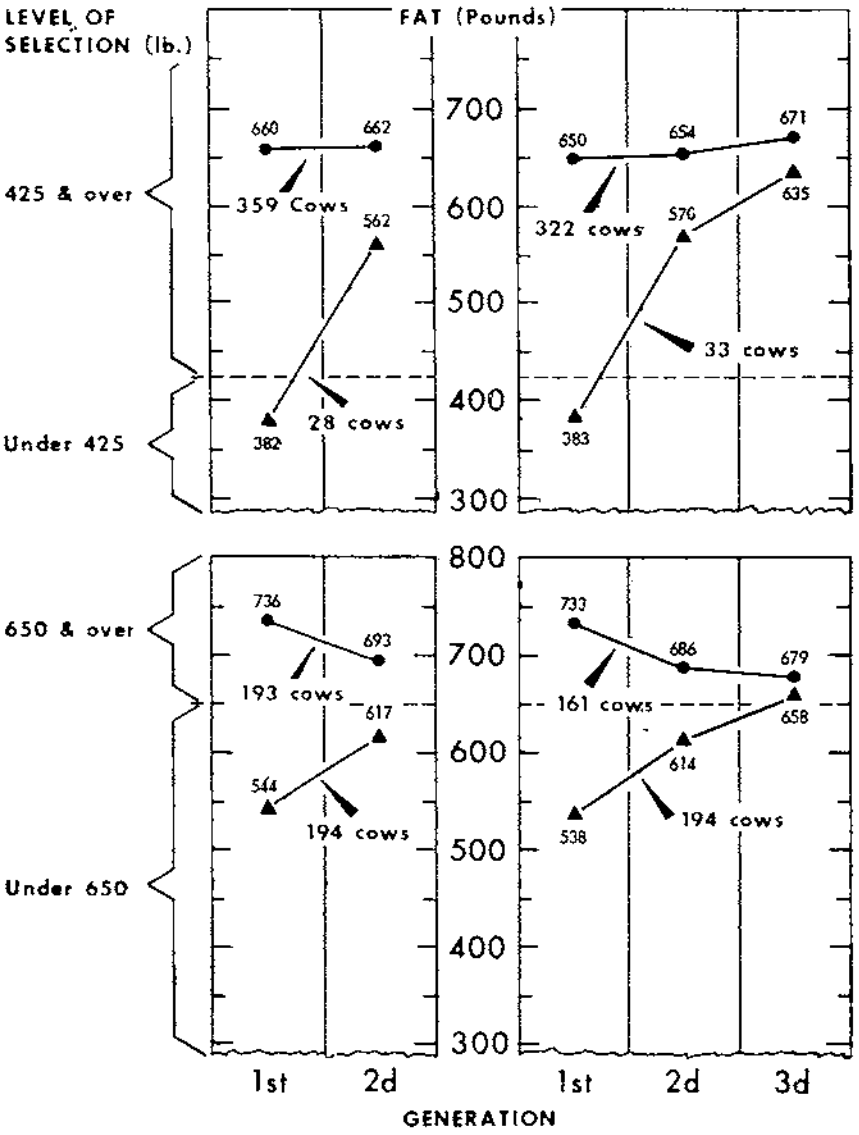

FIGURE 4.—Effect on succeeding generations of selecting original dams at two levels of butterfat production.

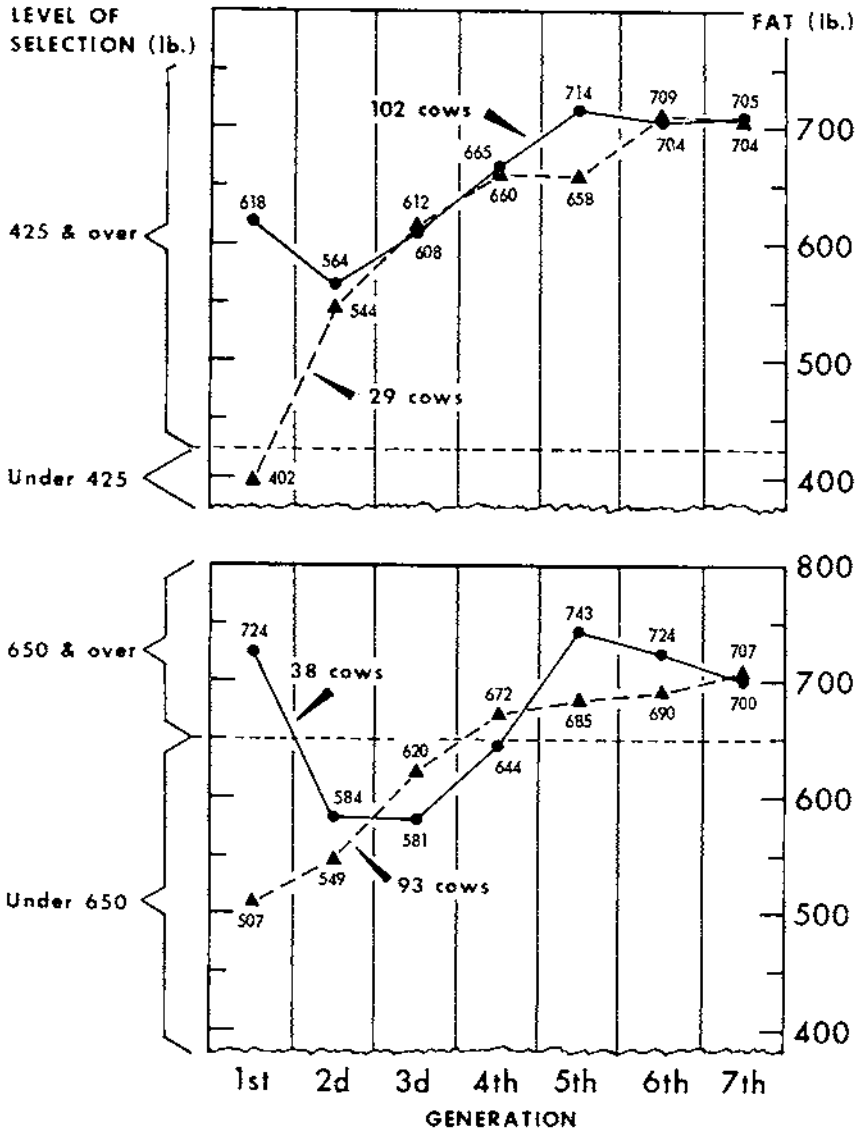

FIGURE 5.—Effect on succeeding generations of selecting original dams at two levels of butterfat production.

prepared for this purpose. These graphs indicate the progress made by descendants of cows with records below 425 pounds of butterfat as compared to those of all other cows, and additional information is supplied by including a breakdown of the descendants of cows that produced more and less than 650 pounds of fat. In the latter comparison, all differences in the levels of descendants have been eliminated in two generations.

Results by Generations When Only Production Proved Sires Were Used

The foregoing analysis includes data on all females in the Beltsville herd that were part of the breeding research program. The major project was planned to determine the results of the continuous use of unrelated proved sires. The complete study, as previously explained, includes some inbreds, some linebreds, and a few daughters of young bulls. By excluding all animals except those with straight descent from the production-proved sires, it is possible to show by generations the results of uninterrupted use of such sires.

Records were completed by 21 cows in the last 3 generations while the main body of the analysis was being prepared. They were available for this portion of the study and have been included in the averages (table 27). The addition of 3 animals to the sixth generation, 12 to the seventh, and 6 to the eighth did not materially alter the results.

Probabilities

The best measure of progress in developing producing ability in a dairy herd is the increase in production as the sequence of generations in the herd increases. Assuming a constant environment, it can be said that in a random-bred herd, where females and males are approximately average for the breed in transmitting ability, the number of increases and decreases would be about the same.

In a breeding experiment of this kind where production-proved sires are used, some measure of the success of the operation might be indicated by the extent to which increases exceed decreases. With this in mind, a tally was made of the increases of all project cows over all their female ancestors.

The total possibilities of measuring differences between individual cows and their female ancestors numbered 5,470. Of this number, 3,591 showed increases, and this was 65.7 percent of the total.

There is much repetition in this number 5,470, and for this reason another tabulation was tried where a comparison was made of the individuals in each generation with their array of female ancestors. This resulted in a total of 1,739 comparisons, of which 1,184, or 68.1 percent, showed increases. A generation breakdown of these figures is given in table 28.

The data already discussed, which show the effect of female selection on production, are also of interest in studying the effect of the level of production on the proportion of increases and decreases in various lines of descent. The descendants of cows that produced less than 425 pounds of butterfat were separated from those of all cows, and the proportion of increases compared with that of the whole population, but the determinations were limited to only the female ancestors of the individuals in each generation. The results of this breakdown are shown in table 29.

TABLE 27.—*Average butterfat production as affected by continuous and by interrupted sequence of proved sires, by generation*

Generation	Continuous sequence of proved sires				Interrupted sequence of proved sires				Total			
	As originally analyzed		With additions [1]		As originally analyzed		With additions [1]		As originally analyzed		With additions [1]	
	Number	*Pounds*	*Number*	*Pounds*	*Number*	*Pounds*	*Number*	*Pounds*	*Number*	*Pounds*	*Number*	*Pounds*
1st	33	530	----	----	2	612	----	----	35	535	----	----
2d	31	564	----	----	5	500	----	----	36	555	----	----
3d	29	609	----	----	22	603	----	----	51	606	----	----
4th	39	693	----	----	32	649	----	----	71	673	----	----
5th	40	703	----	----	27	686	----	----	67	696	----	----
6th	47	705	49	709	24	681	25	677	71	698	74	698
7th	23	713	32	707	14	705	17	701	37	710	49	705
8th	8	711	13	728	15	724	16	718	23	720	29	722

[1] Includes records completed by cows while the original analysis was being made.

TABLE 28.—*Increase in average butterfat yields by the members of each generation as compared with all their female ancestors*

Generation	Comparisons	Increase	
	Number	*Number*	*Percent*
1st	35	13	37.1
2d	72	41	56.9
3d	153	96	62.7
4th	284	204	71.8
5th	330	241	73.0
6th	425	286	67.3
7th	258	170	65.9
8th	182	133	73.1
Total or average	1,739	1,184	68.1

TABLE 29.—*Increase in average butterfat yields by the descendants of cows that produced less than 425 pounds of fat as compared with all their female ancestors, by generation*

Generation	Comparisons	Increase	
	Number	*Number*	*Percent*
1st	5	5	100.0
2d	14	13	92.9
3d	18	15	83.3
4th	48	39	81.3
5th	70	52	74.3
6th	95	69	72.6
7th	21	13	61.9
8th	24	16	66.7
Total	295	222	75.3

The data in table 30 are self-explanatory. The last two lines show that all daughters of dams that made less than 425 pounds of fat were plus daughters. This was the level at which the final basis for theoretical selection was set, as previously reported.

A measure of progress in breeding dairy cattle might be expressed in the amount by which the increase of daughters of the lower producing cows exceeds the decrease of daughters of higher producing cows.

TABLE 30.—*Daughters in each generation that were better and that were poorer producers than their dams, grouped according to production level of their dams*

Group	Generation								
	1st	2d	3d	4th	5th	6th	7th	8th	Total
All dams:									
All daughters.....number..	35	36	51	71	66	70	37	21	387
Daughters better than dams.....percent..	37. 1	69. 4	68. 6	62. 0	48. 5	42. 9	54. 1	67. 1	54. 5
Daughters poorer than dams.....do....	62. 9	30. 6	31. 4	38. 0	51. 5	57. 1	45. 9	42. 9	45. 5
Dams produced 650 pounds or more:									
All daughters.....number..	12	1	9	34	42	51	29	15	193
Daughters better than dams.....percent..	8. 3	0	22. 2	41. 2	35. 7	31. 4	41. 4	40. 0	34. 2
Daughters poorer than dams.....do....	91. 7	100. 0	77. 8	58. 8	64. 3	68. 6	58. 6	60. 0	65. 8
Dams produced less than 650 pounds:									
All daughters.....number..	23	35	42	37	24	19	8	6	194
Daughters better than dams.....percent..	52. 2	71. 4	78. 6	81. 1	70. 8	73. 7	100. 0	100. 0	74. 7
Daughters poorer than dams.....do....	47. 8	28. 6	21. 4	18. 9	29. 2	26. 3	0	0	25. 3
Dams produced less than 425 pounds:									
All daughters.....number..	5	5	13	5	0	0	0	0	28
Daughters better than dams.....percent..	100	100	100	100	----	----	----	----	100

Production Performance of Daughters of Individual Sires

This is a study of a breeding project that was designed to determine the effect on butterfat production brought about by the continuous use of production-proved Holstein sires. The basis for selecting these sires was set forth in the operation of the project, and the following presentation is a report of the performance of the project-bred daughters of the individual sires. The daughters are grouped according to their dams and also by the generation in which they appeared.

Denton Colantha Sir Rag Apple 87426 (Sire No. 1)

This bull sired 33 of the 35 members of the first generation. Analysis of his daughters' butterfat production and that of their dams is as follows:

Group	Comparisons	Average production		Daughters produced—	
		Daughters	Dams	More than dams	Less than dams
	Number	*Pounds*	*Pounds*	*Number*	*Number*
All outbred daughters	33	530	574	13	20
Abnormal daughter	1	202	701	0	1
Normal daughters	32	541	570	13	19
Daughters from—					
3 highest producing foundation cows	11	568	711	1	10
14 other foundation cows	22	511	506	12	10

The unweighted average of 17 foundation cows was 542 pounds of fat.

The breakdown shown in the above table is presented to afford some explanation of the overall performance of this sire. With the abnormal daughter omitted, the remaining 32 average 1 pound less than the unweighted foundation group. When this daughter is not included, one-third of the difference between dams and daughters disappears.

Varsity Derby Matador 234809 (Sire No. 2)

Derby sired 2 first-generation daughters when bred to foundation cows, but his remaining 33 daughters were from daughters of Sire No. 1, and made up the bulk of the second generation.

Comparison of the butterfat production of his daughters with their dams is as follows:

Group	Comparisons	Average production		Daughters produced—	
		Daughters	Dams	More than dams	Less than dams
	Number	*Pounds*	*Pounds*	*Number*	*Number*
1st-generation daughters	2	612	649	0	2
2d-generation daughters	31	564	521	21	10
All outbred daughters	33	566	528	21	12
Inbred daughters (3d generation)	5	447	526	2	3

Pride of the Bess Burkes 294574 (Sire No. 3)

Pride had a limited term of service due to his untimely death. He sired only nine daughters, and two of these were definitely abnormal, as they showed response to hormonal treatment during subsequent lactation periods. One of the abnormal daughters had only male offspring, but the other had two daughters that showed no signs of having inherited their dam's deficiency. The dams of all his daughters were sired by No. 2.

The following tabulation shows the two groups separately:

Group	Comparisons	Average production		Daughters produced—	
		Daughters	Dams	More than dams	Less than dams
	Number	*Pounds*	*Pounds*	*Number*	*Number*
Normal daughters (3d generation)	7	595	556	5	2
Abnormal daughters (3d generation)	2	289	739	0	2
All daughters	9	527	596	5	4

Count Piebe Hengerveld Ormsby 444324 (Sire No. 4)

Count was in service only a short time and died because of a foreign body. He sired only five daughters, four of which were members of the third generation and the other was a member of the fourth.

Group	Comparisons	Average production		Daughters produced—	
		Daughters	Dams	More than dams	Less than dams
Daughters whose dams were by—	*Number*	*Pounds*	*Pounds*	*Number*	*Number*
Sire No. 2 (3d generation)	4	628	600	1	3
Sire No. 3 (4th generation)	1	649	511	1	0
All daughters	5	632	582	2	3

Chief Piebe Ormsby Burke 444088 (Sire No. 5)

Chief was in active service at Beltsville for more than 5 years, and a comparison of his various daughter groups with their dams is shown.

Group	Comparisons	Average production		Daughters produced—	
		Daughters	Dams	More than dams	Less than dams
Outbred daughters—					
Whose dams were by—	*Number*	*Pounds*	*Pounds*	*Number*	*Number*
Sire No. 2	19	657	586	15	4
Sire No. 3	13	723	565	11	2
Sire No. 4	14	641	649	7	7
Sire 905	6	713	632	4	2
All outbred daughters	52	676	603	37	15
In 3d generation	16	650	577	12	4
In 4th generation	31	695	612	23	8
In 5th generation	5	641	630	2	3
Inbred daughters—					
In 4th generation	3	588	691	0	3
In 5th generation	2	627	615	1	1
In 6th generation	1	534	562	0	1
All inbred daughters	6	592	645	1	5

Douglas Buttercup Hark 660575 (Sire No. 6)

Douglas also had a long enough period of service to establish his worth in the Beltsville herd. He sired daughters in the 4th, 5th, 6th, and 7th generations, and comparisons of the butterfat production of his daughters with that of their dams is indicated.

Group	Comparisons	Average production		Daughters produced—	
		Daughters	Dams	More than dams	Less than dams
Outbred daughters—					
Whose dams were by—	*Number*	*Pounds*	*Pounds*	*Number*	*Number*
Sire No. 5	39	710	684	24	15
Sire 905	5	740	816	0	5
King	2	693	593	2	0
All outbred daughters	46	713	695	26	20
Inbred daughters	2	671	753	0	2
Daughters in—					
4th generation	14	713	716	8	6
5th generation	26	718	697	15	11
6th generation	7	668	690	2	5
7th generation	1	799	636	1	0

Rose Hill Emperor Governor 743892 (Sire No. 7)

Governor was the last of the series of production-proved sires brought to Beltsville for this project. Subsequently the program was carried forward by the use of semen from artificial breeding stud bulls. He sired daughters in five generations, from the fourth to the eighth, inclusive. Because of lack of space, his five inbred daughters were moved from the herd before they made production records.

Group	Comparisons	Average production		Daughters produced—	
		Daughters	Dams	More than dams	Less than dams
Outbred daughters—					
Whose dams were by—	*Number*	*Pounds*	*Pounds*	*Number*	*Number*
Sire No. 6	48	708	716	20	28
Sire No. 5	12	695	696	5	7
Sire 905	7	687	670	4	3
All outbred daughters	67	704	708	29	38
In 4th generation	3	621	690	0	3
In 5th generation	25	693	703	10	15
In 6th generation	28	712	726	12	16
In 7th generation	9	717	650	6	3
In 8th generation	2	787	799	1	1

Sir Gerben Colantha Rube 514310 (Beltsville Herd No. 379)

This bull was a son of Sire No. 2 from a daughter of Sire No. 1. He was bred to daughters of Sire No. 1 to produce a linebred group to compare with the outbreds sired by Sire No. 2. His daughters in turn were bred to Sire 905, and this bull was later brought into the proved sire project, so it was necessary to include those daughters of Sire 379 whose progeny became part of the experiment. This included two inbred daughters of Sire 379.

The first five daughters are in the second generation, and the other two are members of the third generation.

Group	Comparisons	Average production		Daughters produced—	
		Daughters	Dams	More than dams	Less than dams
	Number	*Pounds*	*Pounds*	*Number*	*Number*
Linebred daughters from dams by Sire No. 1	5	500	491	4	1
Inbred daughters from dam by Sire 379	2	628	314	2	0

Pride Ormsby Gerben Colantha Ona 603883 (Beltsville Herd No. 905)

This bull was a son of Sire No. 3 from a daughter of Sire No. 2, and was used first to produce a linebred group from daughters of Sire No. 2 to compare with the outbreds. After an outbreak of TB had depleted the herd in 1935 and 1936 some of his daughters were used to build up the project, as he was by that time a proved sire. King Ormsby of Iodak was introduced into the herd to follow Sire No. 5, but he died suddenly, and in order to keep the project moving until a suitable replacement could be found, Sire 905 then had a short period of service on the proved sire project. He was available for use for a long time and was mated to daughters of a number of bulls.

By way of explanation of the levels in the fourth generation group, four of these were from inbred dams and they averaged 556 pounds, their dams 490. In the remaining 10 pairs, the daughters averaged 667 and the dams 624 pounds.

Group	Comparisons	Average production		Daughters produced—	
		Daughters	Dams	More than dams	Less than dams
Daughters whose dams were by—	*Number*	*Pounds*	*Pounds*	*Number*	*Number*
Sire No. 2	11	652	513	9	2
Sire No. 3	2	668	491	1	1
Sire No. 5	4	736	715	3	1
Sire 379	5	610	537	4	1
Sire 1314	4	683	650	3	1
Sire 1393	2	619	693	1	1
All daughters from dams by other sires	28	657	572	21	7
Inbred daughters from dams by Sire 905	5	680	704	2	3
Daughters in—					
3d generation	12	666	530	10	2
4th generation	14	636	586	9	5
5th generation	4	755	756	3	2
6th generation	2	519	693	1	1

Lauxmont Rag Apple Autocrat 741318 (Code H–3)

This was the first bull in artificial breeding used long enough to have a sizable get. He was in service in the First Pennsylvania ABA at Lewisburg, Pa. His 22 daughters in the Beltsville herd averaged 730 pounds of butterfat, but only 19 of these were from dams with records.

Two daughters in the eighth generation whose dams had no production records made 879 and 651 pounds, which brings the average of eight daughters in the eighth generation up to 714 pounds of fat. The other daughter from an untested dam was in the sixth generation, and her record of 750 pounds did not change the average for that group.

Group	Comparisons	Average production		Daughters produced—	
		Daughters	Dams	More than dams	Less than dams
Daughters whose dams were by—	*Number*	*Pounds*	*Pounds*	*Number*	*Number*
Sire No. 7	17	715	677	11	6
Sire No. 6	1	904	904	1	0
Sire 2152	1	731	642	1	0
All daughters	19	726	687	13	6
Daughters in—					
6th generation	6	754	670	6	0
7th generation	7	726	683	5	2
8th generation	6	697	710	2	4

S J C Valley Emperor Star 857269 (Code H–24)

This bull was in service in the Southeastern Pennsylvania ABA, and he sired a total of 31 daughters in the Beltsville herd. Records of 28 were available when this study was made.

Group	Comparisons	Average production		Daughters produced—	
		Daughters	Dams	More than dams	Less than dams
Daughters whose dams were by—	*Number*	*Pounds*	*Pounds*	*Number*	*Number*
Sire No. 7	20	672	687	8	12
Sire No. 6	4	662	748	0	4
Jerry	1	795	686	1	0
Code 511	1	752	718	1	0
Code 802	1	616	739	0	1
Sire 2577	1	762	686	1	0
All daughters	28	678	699	11	17
Daughters in—					
6th generation	14	656	696	3	11
7th generation	8	675	693	4	4
8th generation	6	733	712	4	2

Knollwood Alcartra Chieftain 847579 (Code 802)

The New York Artificial Breeders' Cooperative was the owner of this sire. His 14 daughters in the Beltsville herd averaged 730 pounds of butterfat. This analysis dealt with only the 12 that had completed records when the data were assembled, and they were members of the sixth, seventh, and eighth generation groups.

Group	Comparisons	Average production		Daughters produced—	
		Daughters	Dams	More than dams	Less than dams
Daughters whose dams were by—	*Number*	*Pounds*	*Pounds*	*Number*	*Number*
Sire No. 7	10	719	761	4	6
Sire No. 6	1	801	790	1	0
Code H–3	1	703	645	1	0
All daughters	12	724	754	6	6
Daughters in—					
6th generation	6	754	769	4	2
7th generation	4	690	754	1	3
8th generation	2	704	709	1	1

No detailed report is included on those sires that had only a few daughters each in this study, as the limited information on these bulls would not be sufficiently informative to be of any help.

Table 31 is included to show the distribution of the gets of all sires throughout the eight generations.

TABLE 31.—*Number of daughters of each sire and the generations in which they appeared*

Sire	Generation							
	1st	2d	3d	4th	5th	6th	7th	8th
No. 1	33							
No. 2	2	31	5					
379		5	2					
No. 3			9					
No. 4			4	1				
No. 5			16	34	7	1		
905			12	14	4	2		
1314			3		1			
No. 6				14	27	7	1	
King				1	1	1		
1373				3				
1393				1	1			
No. 7				3	25	28	9	2
2152					1			
Code H-3						7	7	8
Code H-24						14	8	6
Code 802						6	4	2
Jerry						1	1	
Code H-8						2	2	2
1779						1		
2577						1		
Code 503							1	
Code 511							1	
Code 15104							3	1
Code 810								1
Code H-35								1

Summary

Breeding investigations with dairy cattle were inaugurated in 1917 as part of the research program of the U.S. Department of Agriculture. The objective of this experimental work was to provide breeders and dairy farmers with a more complete understanding of the laws of heredity as they apply to the breeding of dairy cattle for economical and profitable production of milk and butterfat.

The principal research study with Holstein-Friesian cattle called for the continuous use of unrelated production-proved sires to develop a strain that would steadily improve in its inheritance for a high level of milk and butterfat production. In addition, linebred groups were to be bred from the stock so that both the outbred and the linebred groups would start from the same basis of heritage. Another procedure followed in a limited way was to breed the first

daughters of proved bulls to their own sires. This inbreeding was carried out as a means of providing a closer check on the genetic makeup of the sires and possibly unmasking hidden recessives.

The study was originally designed to be operated on a single-sire-per-generation basis. In the early years it was possible to meet this requirement fairly well. However, the loss of certain bulls before they had met the expected requirements in number of progeny necessitated deviations from this part of the design. Also, about the time the seventh purchased proved sire had daughters of breeding age, the rapid growth of artificial breeding had developed a highly competitive situation in the proved bull market. Therefore, the study was continued from this point on by utilizing the service of selected sires available in cooperating bull studs of Pennsylvania and New York. Certain emergencies during the 35 years of the study necessitated the occasional use of Beltsville-bred bulls. The progeny of these bulls became part of the project when they had daughters sired by other proved bulls.

No culling or selection of females was practiced after the foundation herd was established. The only selection practiced was in the choice of bulls. All female progeny of the various sires were raised and developed without regard to appearance or producing ability of themselves or their dams.

Every effort was made to provide conditions of environment and management that could be made continuously uniform. The cows were kept in box stalls. A modified Savage feeding standard was used to determine the nutritive requirements based on weight and production at the beginning of each month. No pasture was provided. Exercise was permitted in a dry lot. All cows were encouraged to eat hay and silage by offering them slightly more than they would consume, and the grain ration was apportioned to make up the rest of the nutrients required for maintenance and production.

Production records were made under the supervision of the University of Maryland and in accordance with the rules of the Holstein-Friesian Association of America. The cows were milked three times a day for 365-day records until late in 1951. After that the procedure provided for two milkings for 305 days. All the data in this study are based on mature-equivalent best records made on two milkings daily for 305 days or adjusted to that basis.

The foundation herd of 34 females was made complete by supplementing the small group of animals already at Beltsville with the purchase of 22 cows in 3 lots during the spring of 1918 from Minnesota, Ohio, and New York. Only half (17) of these assembled females produced daughters for the project. This half of the foundation herd averaged 542 pounds of fat. They ranged from 765 to 377 pounds.

In all, 26 sires were used. Eight were purchased as proved sires, 10 were proved sires used in cooperation with artificial breeding studs, and 8 were sires bred from the Beltsville herd.

The average butterfat production for the eight generations of data available for analysis was 535 pounds for the first generation; 555 for the second; 606 for the third; 673 for the fourth; 696 for the fifth; and 698, 705, and 720 for the sixth, seventh, and eighth, re-

spectively. A 154-pound increase was shown for the first five generations and 24 pounds from the fifth generation to the eighth. Some increase in variability occurred up to the third generation and then, after a quick drop, a gradual decline ensued. An analysis was also made excluding all animals except those with straight descent from the production-proved sires. The results from this additional analysis were very similar to the results for the entire herd. In general, the cows of any given level of production had better producing daughters as the generations advanced.

A study of the relation of individual merit to transmitting ability was carried out by grouping the project animals according to the levels of their own performance. Only 15 percent of the daughters appeared in the same butterfat production class as their dams. This indicates the wide range of production for daughters of cows having similar production. This range is further illustrated by the fact that 193 daughters of cows that produced over 650 pounds of butterfat ranged in production from 200 to 900 pounds with an average of 693 pounds. The 194 daughters of cows that produced less than 650 pounds ranged from 200 to 900 pounds, with an average of 617 pounds.

The conduct of this breeding experiment entirely without culling daughters of any cow regardless of the dam's production made it possible to estimate what the results would have been if such a policy of selection had been incorporated. The data were analyzed to determine the results of discarding daughters of all cows that produced less than 400, 410, 420, and 425 pounds of butterfat. A total of 21 cows had records of less than 425 pounds. Culling all daughters of these cows and the consequent exclusion of their descendants removed from the analysis 176 cows that averaged 661 pounds of butterfat. The 215 cows that were not excluded because of culling averaged 651 pounds of fat. These results show the ineffectiveness of heifer selection based on a low level of the dam's fat production.

An analysis was made to determine the impact of selection on succeeding generations and the length of time that occurred before its effect was lost. The large increases made by daughters of the low-producing cows in most groups placed them quite close to the level of the daughters of all other cows. Usually in two generations the progeny of low-producing cows were about equal in ability to those of the rest of the group. Thereafter there was little to choose between the descendants of either group of cows. Such results can only be expected when good transmitting sires are used.

There were 1,739 comparisons between project females and their female ancestors and in 1,184 cases, or 68.1 percent, the descendant produced more butterfat. This might be compared to the expectation in a herd where no improvement is being made, of approximately 50 percent of the descendants showing increases.

A measure of progress in breeding dairy cattle might be expressed in the amount by which the increase of daughters of the lower producing cows exceeds the decrease of daughters of higher producing cows.

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