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THE INHERITANCE OF MILK-YIELD IN CATTLE.

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VII.

THE INHERITANCE OF MILK-YIELD IN CATTLE.

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[Read May 23. Published June 12, 1911.]

Until recently it was the common belief that variation among domestic animals was a slow and gradual process, and that, if a breed was improving, the increments of improvement from generation to generation were small and frequently imperceptible. Holding this belief, the general policy of stock-breeders was to persist in breeding not only from such stock as were obvious advances, but also from such as were believed to be potential advances, upon their parents. So, our present breeds were believed to have been "developed" from an ancestry by no means noteworthy in attainments. In each breed a few stock-breeders were usually pre-eminently successful, and stock of their breeding or of their "blood" were largely sought after by others less successful. If a great sire or dam could not be secured, then his or her son or grandson, or a descendant still farther removed, was considered more desirable for breeding purposes than another animal equally good or even better as such, but less illustrious in pedigree. A near descendant of some great sire or dam was always more desirable, of course, than another more remote, for it was considered more likely to have inherited its ancestors' tendency to improvement.

This policy no doubt raised the general average, increased the number of animals that were up to the average attainment, but it also produced many disappointments, many that "harked back" to remote and less improved ancestry, although these were forgotten in the occurrence of others high above the average of their day.

The difficulties of this policy were greater when applied to dairy than when applied to "beef" breeds or to horses bred for strength or speed. In these other cases the characters that determined whether a young animal was likely to fulfil the purpose for which it had been bred were more obvious. There was a method by which good dairy stock might have been told,

and so improved as quickly as other stock; but this method was not adopted till quite recently. Breeders persisted in relying upon what they took to be the outward signs of good dairy cattle rather than adopt the only sure and reliable method by which they could be identified. Some of the signs they relied upon are, no doubt, of value, as, for instance, the character and size of the udder; but others, such as the wedge-shaped shoulder, the long, thin neck, the long head—in some breeds it has to be short—and a general unwillingness to lay on "flesh," or, rather fat, to say nothing of such things as a thin tail or the way the hairs are turned upon the udder, are open to serious doubt. As an instance of the unreliability of one of these signs only, and that, perhaps, the most important, since it involves some of the others, it need only be mentioned that cases of Aberdeen Angus cows giving five and six gallons of milk a day, and of others giving over a thousand gallons of milk during a normal lactation have been recorded, while a well-known Irishman rears three or four, and sometimes even five, calves upon Hereford cows within the year.

There being thus few data in the United Kingdom upon which any theory as to the inheritance of milk-yield could be built up, the present inquiry was begun some five or six years ago by a visit to Denmark, because it was known the Danes had raised the milk-yield of their cows greatly in recent years, and it was hoped a study of their methods might throw some light upon the problem.

Staats Consulent Mörkeberg of Copenhagen gave ready and kind assistance in explaining the method, in suggesting districts and farms to be visited, and in giving introductions to individual breeders. Staats Consulent Appel of Aarhus also wrote about the Danish method, and gave advice as to districts and farmers to be visited. Two years ago an opportunity occurred of meeting Mr. Mörkeberg again and discussing some of the points once more.

The foundation of the Danish method was the keeping of milk records. Upon the evidence furnished by these came the knowledge that many cows were not paying their way or were occupying room that others might occupy to greater profit. Then arose the demand for the sons of good milking cows as stock-bulls.

It was seen from the records that good milkers were usually the daughters of good milkers, and poor milkers the daughters of poor ones. It was seen also that some bulls left better daughters than others; and although, for the want of records, it would not have been easy to prove in the early days that the sires of good milking daughters were usually the sons of good milking dams, it was generally agreed that it was safer to err on the side that presumably had most chances in its favour and assume that milk-yield

was inherited through the sire as well as through the dam. Eventually it became widely accepted that the bull's pedigree as regards milk was of vital importance, and, when the selection of a particular sire was under consideration, his milk-pedigree, so to speak, was examined as far back as it could be given.

At no time, however, was there any suggestion from Denmark, or from Holland or Sweden, where records had also been kept systematically, that there was any reason to question the theory that improvement was a slow and gradual process. But it was clear that, as time went on, the confidence of stock-breeders in the system of selecting the progeny of good milkers for stock purposes rose higher and higher. The visit to Denmark, therefore, did not result in any change of view with regard to the inheritance of milk-yield further than to emphasize the importance of keeping milk records in order to know which stock should be eliminated and which should be bred from.

Three years ago, when it became apparent that Mendel's laws applied to colour, horns, length of limb, and other less important characters in cattle, one of the first questions that suggested themselves was, Is milk-yield also inherited in some Mendelian manner? and the inquiry was begun at once. But the great difficulty was to find data. Two or three years before that time, a number of Ayrshire breeders had commenced to keep records, and an appeal was made to the late Mr. John Speir, who had been at the head of the movement. On Mr. Speir's recommendation, a number of Ayrshire breeders were visited, but their records were not old enough to yield sufficient data. One very important point, however, was brought out in conversation with Mr. Speir, namely, that in a number of cases, where a daughter was an improvement or the reverse upon her dam, the difference between their yields was not small, but large. Cows giving four or five hundred gallons might have daughters giving six or seven; cows giving six or seven might have daughters giving nine; and *vice versa*. Poor milking cows usually had poor milking daughters, and good milking cows good milking daughters; but the rule was by no means invariable. At the same time Mr. Speir had no doubt of the power of a bull to improve or damage a herd, and to leave daughters of very unequal capacity. Unfortunately no note was taken of the cases Mr. Speir had in his mind, as it was never thought but that he would be alive to be referred to again and again. Some of his cases are referred to in his Milk Record Reports, published in the Transactions of the Highland and Agricultural Society of Scotland during the years 1904 to 1910, and others in a lecture on "Milk Records," delivered in December, 1907, and published by the Scottish Agricultural Publishing Company.

In dairy literature of recent years much had been written of the great

advance made in America in breeding high-yielding dairy stock, and advantage was taken of the meeting of the British Association at Winnipeg, in 1909, to make inquiry into the question in Canada and the United States. Herds were visited at a number of colleges and experiment stations as well as at some farms in both countries. But here again there was little more information to be gained. The records were not old enough. Besides, many of the American records are confusing, for the reason that they usually state the butter-yield rather than the milk-yield for a lactation or for a year. The butter-yield depends mainly upon two factors, which are inherited independently, namely, the milk-yield and the proportion of butter-fat it contains. Consequently a statement of butter-yield conveys no accurate information either as to the yield of milk or as to its quality ; and, as a guide in breeding, this method is bound to be elusive and uncertain, since the breeder is not clear as to whether his cows are yielding milk in quantity or in quality. If the branches of a bank report to headquarters the value each has in hand in precious metal, the officials at headquarters will easily add up and find the total sum, but they will have difficulty in determining how much is gold and how much is silver.

It was also found both in the States and in Canada, but especially at colleges and experimental-station farms, that stock-breeders are much influenced by the wedge-shaped shoulder idea : the cause lying to some extent, perhaps, in their system of judging stock by scoring card. So strong is this influence that sons of a narrow-shouldered, low-yielding cow are frequently preferred as stock-bulls to sons of a higher-yielding cow whose shoulder is broad.

The American visit having brought the problem no nearer solution, it was next arranged through the Department of Agriculture and Technical Instruction to have a set of forms on which were printed questions as to the yields in herds of cows, and as to the cows' parentage. These forms were sent to breeders in the United Kingdom who were known to have kept records, and who might be in a position to give information. A number were kind enough to fill up the forms, and among them were found some whose herds were large enough and whose records were old enough to supply data suitable for the purpose in hand. The answers showed, however, that a considerable amount of preliminary investigation was necessary before the data could be made use of. Breeders had been asked to give the records of each cow for as many years as possible and to state the cows' ages against their records for each year. They were also asked to state over against each record the length of the lactation concerned. From the answers to these questions it was seen that in order to compare each cow with the others, it

would be necessary to determine, as closely as such a matter would permit, how far the yield of a cow is increased when her lactation exceeds the normal, and how far it is decreased when the lactation period is shortened. The normal lactation is, of course, taken to be that in which the next calf is born about twelve months after the previous one. It was also necessary to determine how much a cow's annual yield increases with her age.

For these objects the records of the herds kept at the Department of Agriculture's farms, as also a number of Dutch and Danish herd-books, in which cows' yields are recorded, were examined. But the examination of these books showed also that still other circumstances would have to be taken into account.

A cow's yield is exceedingly sensitive and liable to be affected by many causes. The chief of these were found to be food and weather and time of calving. An examination of the records at Glasnevin, which have been kept since 1890, showed that the combined yields of the herd rise and fall at certain seasons, sometimes very considerably. From November to January, when the cows are on the usual winter food of hay, roots, and concentrates, the yield is practically constant; but it falls in February and rises again in March. Early in May, just at the time the cows are put out on the pastures, it falls again, but only for a week or so. Then it rises quickly, and till about the end of June or the beginning of July it remains at from 10 to 20 per cent. above the winter yield. During July and August, depending on the rainfall, it falls again; and, in October, until the cows are housed for the winter, it is usually at its lowest. These variations have considerable effect upon the cows' total yields. A cow calving between December and the end of February has the advantage of the rise produced by pasture before her yield has dropped far, and, in consequence, if she be a very good one, may give a hundred or even a hundred and fifty gallons more during a normal lactation than another very good cow calving between May and September.

It was also found, of course, that illness and abortion, and such things as injury to the udder, caused the yields to fall; but several causes had results that would not be generally expected. It is a common belief that a cow that fattens up before calving cannot milk well. This, if not disproved directly, is disproved indirectly by the Glasnevin figures; for the cows that continue to yield up to the end of the previous lactation, and therefore do not recover "condition" before calving, fall off in yield during their next lactation. It is also disproved by the fact that breeders who exhibit cows at milking trials almost invariably feed their cows well for some time before calving. One well-known breeder believes that the difference between a good cow lean and

the same cow fat before calving may represent as much as a hundred gallons, or even more, during a lactation. It was also found that, if a cow was got in calf again too soon, her yield fell during that lactation: very seriously when the "rest" was below six weeks.

These points referred to above having been considered so far that their influence might be estimated where necessary, the effect of a prolonged lactation upon the yield was examined.

A comparison of the records of the cows got in calf at the normal time, that is three months after the previous calving, with those of the cows running beyond that time, or not got in calf at all, showed that cows are, on the average, usually about three months in calf before their being so affects the yield appreciably. The yield of a normal cow drops fairly quickly from about the sixth month after calving till about the tenth month, when it ceases altogether. On the other hand, the yield of a cow that is not in calf till more than three months after her last calving is so much later in showing the quick drop which shows the yield is coming to an end. There is a decline certainly, but it is small. Consequently, a cow that goes thirteen months from calf to calf milks for a month longer than one that goes twelve months. And thus, for every month a cow is in milk beyond the normal, the yields she gives during the seventh, the seventh and eighth, the seventh, eighth and ninth months of her lactation, and so on, must be deducted from the total yield in order to bring it to the normal. This deduction must be made with some judgment, of course, because no cow will go on milking for ever, and the drop at the end of a very long lactation will not be the same as it would have been had the lactation been normal.

While examining the Irish records it was noticed that the daily yield of a cow when at her maximum, from four to six weeks after calving, is a fair index of what the total normal yield will be for the same lactation, provided, of course, no illness or accident intervenes to alter the yield. A winter-calving cow that gives a daily yield of six gallons at her maximum will rise to about eleven or twelve gallons during the lactation; a cow that gives over five gallons will rise to about a thousand. Cows calving in spring or summer will not rise so far. The calculation is to multiply the average daily yield in pounds over two or three weeks at the maximum by about twenty, and the result gives an approximate indication of the yield for the normal lactation in gallons. A lower figure, say nineteen or eighteen, has to be used for cows calving in spring or summer. Lower figures must be used also where cows are not well fed and cared for. In the case of cows that dry up very early, say in six or seven months, this calculation is misleading; but the number of such cows is not large—far less than is frequently asserted.

It was also noticed that the yield of a cow calved six months and in calf about the normal time is approximately 50 to 60 per cent. of the yield at its maximum. That is to say, a cow whose maximum is sixty pounds a day, gives from thirty to five and thirty pounds when six months calved. The percentage is higher for a winter-calved cow, and lower for a cow calving in spring.

This and the previous observation can be used to reduce a prolonged lactation to the normal when only the total yield is known. For instance, thousand-gallon cows give over 5 gallons a day. At six months calved they give $2\frac{1}{2}$ to 3 gallons a day. If the lactation has been prolonged, say, a month, then 75 to 90 gallons ($2\frac{1}{2} \times 30$ days or 3×30 days) have to be deducted from the total yield to reduce it to the normal, according to the time the cow calved and other affecting circumstances.

The last point to be determined before milk-yields could be compared was the rate at which they increase with age. This is perhaps the most important of all the points dealt with, since there are more young cows than old, and since the young ones are perhaps more satisfactory for the purpose of comparing yields than the old ones. The younger the cow the less are the chances that her yielding-capacity may have been damaged by one or more of the causes liable to do so. At the same time it should be noted that the yield of an immature heifer, say one poorly nurtured or under about two and a half years' old, is probably an unreliable guide. At any rate, none such is relied upon in this paper.

In working through the records at the Department of Agriculture's farms at Glasnevin, Clonakilty, and Loughrea, it became apparent that a cow's yield generally increases from the birth of her first calf, when she is a three-year-old (that is, from about thirty-three to forty-two months old) till the birth of her fourth or fifth, when she is six or seven years old, and that the total increase from the first to the fourth or fifth calf is on the average about 50 per cent. That is, assuming no interference, a cow that starts at 300 gallons will rise approximately to about 450; another that starts at 500 will rise to about 750; and another that starts at 700 will rise to about 1,050.

This estimate was also found to hold as regards Danish and Dutch cows. The records in the first three volumes, containing over 400 cows, of the Herd-book of the red Danish breed (Kostambog Köer af röed dansk Malkerace), published 1907, 1908, and 1910, were gone through carefully, and the results were found to be generally in accordance with the rule. There were exceptions, but these were usually explained by such things as illness or abortion. Among the highest grade of cows, there was one kind of exception which was very suggestive. There were a number of three-year-old cows

giving 800 gallons and over during a normal lactation. In the following years these did not all increase in their yields so regularly as the others; some even fell back the next year; but such as remained productive till they were five or six years old rose to the 1,000 gallon stage or over. In these cases, it is a fair suggestion that they probably overdid themselves by milking too long as three-year-olds, and did not recover sufficiently to give their full yield in the next lactation or even in the next again.

The estimate also was substantially confirmed for the highest class cows by the reports of the milking trials of the last twelve London dairy shows. At these shows the cows are milked two days, and the average yield for one day is calculated from the total : due allowance being made for cows that are more than sixty days calved. Most of the cows exhibited are of the highest class. The few that are otherwise have been eliminated. The following table shows the rate of increase. It should be noted that there has been no class for three-year-old cows till recently, consequently their numbers are small, and that few four-year-olds have been exhibited because they have had to compete with mature cows. The few cows that have been exhibited over ten years old are no doubt abnormally good ones.

Number of cows.	Age of cow. Yrs.	Yield per day. lb.
14	3	39·3
7	4	47·0
35	5	51·6
60	6	55·4
50	7	56·9
30	8	58·0
12	9	54·2
7	10	56·9
5	11 and over	60·1

Having discussed the most important circumstances that may have to be taken into account in estimating a cow's normal yield at maturity, we can now consider the manner in which the capacity for yield is passed on from one generation to another. First of all, we shall show that improvement, or the reverse, is not gradual, but abrupt and sharp: that if a daughter is not on an approximate equality with her dam as a milk-producer, she is either much higher or much lower.

This can be shown by quoting the yields of the cows entered in the first volume of the red Danish herd-book along with those of their dams, granddams, and so on, where such are known. In this herd-book the cows' ages, as well as the dates at which their calves were born, are nearly always given.

Thus in nearly every case allowance can be made for age; and abnormally long or short lactations can be brought to the normal. Abortions, inflammation of the udder, and similar mishaps are frequently mentioned, and can also be taken into account.

It cannot be expected that the normal yield of every cow can be estimated precisely; but approximate accuracy can be attained in most cases, and, as will be seen, the variations are so wide that approximate accuracy is enough. Where there is some doubt it is indicated, but it is never, or very seldom, great enough to put a cow in her wrong grade.

[RECORDS OF RED DANISH COWS AND THEIR DESCENDANTS.

Records of Red Danish Cows and

Herd-Book No. under which records are entered.	Dam.			Daughter.			Granddaughter.		
	Name.	When born.	Yield.	Name.	When born.	Yield.	Name.	When born.	Yield.
1	Korup iii, . .	1890	650	No. 2 Christiane, .	1894	900	—	—	—
3	No. 15 Punktum, .	1882	800	No. 1 Inger, .	1892	850	—	—	—
4	Do. . . .	—	—	No. 13 Punktum, .	1894	800	—	—	—
5	No. 1, . . .	1892	1000	No. 7, . . .	1898	1000	—	—	—
6	No. 18, . .	1878	800	No. 5, . . .	1884	750	No. 5, . . .	1894	800
7	No. 21, . .	1884	750?	No. 34, . .	1891	900?	No. 17, . .	1894	900
8	No. 14, . .	1884	750?	No. 35, . .	1891	850	No. 25, . .	1894	1100
9	Elna, . . .	1883	750	Johanne, . .	1890	850	Sella, . . .	1893	850?
10	Praemieko No. 1, .	1879	750	No. 7 Christiane, .	1890	750?	—	—	—
11	No. 5 Mine ii, .	1889	750	No. 11 Mine iv, .	1891	750	—	—	—
12	Malvine, . .	1884	800?	Fylla, . . .	1889	550	Fylla ii, . .	1896	750?
13	Emma, . .	1882/3	700	No. 11 Emma ii, .	1891	850	—	—	—
14	Martha, . .	1886/7	550	No. 22 Martha ii, .	1893	800	—	—	—
15	Mariane i, . .	1866	550	Braekben, . .	1877	750	No. 34 Mariane iv,	1889?	750?
16	Koen Jörgen, .	1878/9	550	No. 42 Jörgen ii B,	1892	800	—	—	—
17	Koen Hans, . .	1868	550	Hoidfodede Hans,	1877	650	Koen Hans iv, .	1885	?
18, 19	Blomsten i, . .	1876/7	950	Blomsten iii, .	1888	900?	No. 14 Blomsten iv,	1896	1000
20	No. 13 Laura ii, .	1888	800	No. 14 Laura iii, .	1890	750?	No. 2 Laura v, .	1893	750?
22	Hans, . .	1874	800?	Mathilde, . .	1880	800	Johanne, . .	1883	800
23	Gl. Susanne, .	1886	750	Gine, . .	1889	750	No. 9 Gine ii, .	1896	750
24, 25	No. 4 Damgaard, .	1892	950	No. 7 Kirsten, .	1895	1200	—	—	—
26	No. 5 Hanne, .	1892	1400	No. 3 Kella, .	1898	1200	—	—	—
28	Gl. Kam, . .	?	750?	No. 14 Kristine, .	1890	1000	No. 16 Henriette, .	1896	900
29	Poul i, . .	1869	650	Poul ii, . .	1879	950	Poul iv, . . .	1882	950?
47	Do. . . .	—	—	Do. . .	—	—	No. 33, . . .	1883	750?
48	Do. . . .	—	—	Do. . .	—	—	Do. . . .	—	—
31	Gamle Vilhelm, .	1873	700?	Gamle Anders, .	1879	750	Anders No. 16, .	1892	800?
32	Gamle Mutter, .	1882	550?	No. 5 Laerken, .	1888	750?	No. 2 Sigrid, . .	1897	850
33	Kristine, . .	1886	750	Fut i, . .	1888	750?	No. 2 Fut ii, .	1890	1050
34	Anna i, . .	1890	650?	No. 9 Anna ii, .	1894	950?	No. 5 Anna iv, .	1898	1050
37	Else i, . .	1886	650	No. 17 Else iii, .	1892	750?	No. 18 Else iv, .	1896	800?
38	Kristen ii, . .	1879	800	No. 4 Kristen iii, .	1887	1000	No. 22 Kristen vi,	1895	1000
39	Gusta, . .	1884	650?	No. 6 Helga, .	1889	850	No. 12 Helga ii, .	1897	850
40	Do. . . .	—	—	No. 9 Mary, .	1893	850	—	—	—
41	No. 1 Betty i, .	1886	800?	No. 3 Betty iii, .	1893	850	—	—	—
42	No. 59, . .	1871	550	No. 20, . .	1881	?	No. 78, . .	1889	750
49	Do. . . .	—	—	Do. . .	—	—	No. 128, . .	1891	1000

GREAT GRANDDAUGHTER.			GREAT-GREAT GRANDDAUGHTER.			GT.-GT.-GT. GRANDDAUGHTER.			Herd-Book No. under which records are entered.
Name.	When born.	Yield.	Name.	When born.	Yield.	Name.	When born.	Yield.	
—	—	—	—	—	—	—	—	—	1
—	—	—	—	—	—	—	—	—	3
—	—	—	—	—	—	—	—	—	4
—	—	—	—	—	—	—	—	—	5
—	—	—	—	—	—	—	—	—	6
—	—	—	—	—	—	—	—	—	7
—	—	—	—	—	—	—	—	—	8
17 Tutta, .	1896	1000	—	—	—	—	—	—	9
—	—	—	—	—	—	—	—	—	10
—	—	—	—	—	—	—	—	—	11
—	—	—	—	—	—	—	—	—	12
—	—	—	—	—	—	—	—	—	13
—	—	—	—	—	—	—	—	—	14
o. 34 Mariane vii,	1898	750?	—	—	—	—	—	—	15
—	—	—	—	—	—	—	—	—	16
No. 44 Hans v, .	1892	950	—	—	—	—	—	—	17
o. 7, Blomsten v,	1899	1000	—	—	—	—	—	—	18, 19
No. 12 Marie v, .	1895	900	—	—	—	—	—	—	20
No. 16 Johanne ii,	1893	850	—	—	—	—	—	—	22
—	—	—	—	—	—	—	—	—	23
—	—	—	—	—	—	—	—	—	24, 25
—	—	—	—	—	—	—	—	—	26
—	—	—	—	—	—	—	—	—	28
oul v, . .	1884	700	No. 5 Holev i, .	1891	900	No. 6 Holev i, .	1898	950	29
. 1, . .	1890	1000?	—	—	—	—	—	—	47
. 84, . .	1894	850	—	—	—	—	—	—	48
o. 1 Anders ii, .	1895	800	—	—	—	—	—	—	31
—	—	—	—	—	—	—	—	—	32
—	—	—	—	—	—	—	—	—	33
—	—	—	—	—	—	—	—	—	34
—	—	—	—	—	—	—	—	—	37
—	—	—	—	—	—	—	—	—	38
—	—	—	—	—	—	—	—	—	39
—	—	—	—	—	—	—	—	—	40
—	—	—	—	—	—	—	—	—	41
13, . .	1893	750	—	—	—	—	—	—	42
6, . .	1895	1000	—	—	—	—	—	—	49

Records of Red Danish Cows and

Herd-Book No. under which records are entered.	Dam.			Daughter.			Granddaughter.		
	Name.	When born.	Yield.	Name.	When born.	Yield.	Name.	When born.	Y
43	No. 66, . .	1877	950	No. 21, . .	1881	750	No. 104, . .	1887	
44	No. 28, . .	1880	850	No. 64, . .	1884	750?	No. 91, . .	1898	1
45	No. 54, . .	1873	750	No. 94, . .	1884	750	No. 111, . .	1895	
46	No. 19, . .	1880	750	No. 102, . .	1885	1100	No. 118, . .	1895	1
50	No. 91, . .	1880	600	No. 83, . .	1884	850	—	—	—
51	No. 54, . .	1873	750	No. 3, . .	1880	750	No. 110, . .	1885	
52	No. 1, . .	1875	650?	No. 55, . .	1887	800?	No. 92, . .	1894	1
54	No. 1, . .	1886	850?	No. 12, . .	1898	850?	—	—	—
58	Koen Ane, . .	?	750	No. 5 Ane, . .	1892	750	No. 26 Anine, .	1897	7
59	Söllinge, . .	1888	650	No. 3 Söllinge, .	1895	1000	—	—	—
60	Maren i, . .	1883	850	No. 8 Maren iv, .	1892	900	—	—	—
61	No. 2 Gamle Dora,	1802	900	Else, . . .	1895	?	No. 1 Elise Sanderum	1898	11
63	No. 1 Torp, .	1894	1100?	No. 10 Musse, .	1897	1000?	—	—	—
64	No. 6 Gregor, .	1892	650?	No. 15 Gregine, .	1897	950?	—	—	—
65	No. 5 Lise, .	1892	800	No. 1 Liseville, .	1899	1000	—	—	—
69	Sofie, . . .	1879	650	No. 9 Sine, . .	1891	850	—	—	—
70	No. 8 Fylla i, .	1892	850?	No. 9 Fylla ii, .	1894	1050	—	—	—
73	No. 3 Lille Mörke,	1885	650?	No. 7 Busse, .	1895	750	—	—	—
74, 75	No. 1 Agnete, .	1888	850?	No. 9 Agnes, .	1894	1150	No. 15 Thyra ii, .	—	
78	No. 27, . .	1889	750?	No. 17 Allerup, .	1895	850	—	—	—
79	No. 11 Villestofte,	1894	900	No. 4 Villestofte, .	1898	900	—	—	
80	No. 5 Slesvig, .	1887	650	No. 22 Stine i, .	1893	650	—	—	
81	No. 2 Maren, .	1888	1000?	No. 7 Olga, .	1894	1000?	—	—	
	Do. . . .	—	—	No. 10 Karen, .	1895	1000	—	—	
84	No. 5 Laryben, .	1878	750?	No. 7 Stjernen, .	1880	750?	No. 19, . .	1883/4	
85	Do. . . .	—	—	Do. . . .	—	—	Do. . . .	—	
88	No. 47, . .	1876/7	550?	No. 18, . .	1884	750	No. 160, . .	1897	
89	Do. . . .	—	—	Do. . . .	—	—	No. 18, . .	1899	
90	Ærenlund, . .	1879	1000	Ærenlund i, .	1883	750	Florine, . .	1886	
92	No. 105, . .	1887	850	No. 150, . .	1895	850	—	—	—
93	No. 90, . .	1891	850?	No. 126, . .	1896	850	—	—	
94	No. 173, . .	1882/3	700?	No. 78, . .	1891	700?	No. 158, . .	1894	
95	No. 83, . .	1881	750	No. 84, . .	1893	700?	No. 95, . .	1896	
96	No. 67, . .	1879	550	No. 39, . .	1891	850	No. 76, . .	1895	
97	No. 113, . .	1884	750	No. 220, . .	1893	1000	—	—	
98	No. 204, . .	1888	750	No. 227, . .	1894	950	—	—	
99	No. 94, . .	1883	1000	No. 222, . .	1892	1000	No. 230, . .	1895	

T GRANDDAUGHTER.			GREAT-GREAT GRANDDAUGHTER.			GT.-GT.-GT. GRANDDAUGHTER.			Herd-Book No. under which records are entered.
e.	When born.	Yield.	Name.	When born.	Yield.	Name.	When born.	Yield.	
. .	1894	750	—	—	—	—	—	—	43
—	—	—	—	—	—	—	—	—	44
—	—	—	—	—	—	—	—	—	45
—	—	—	—	—	—	—	—	—	46
—	—	—	—	—	—	—	—	—	50
105, . .	1894	750	—	—	—	—	—	—	51
—	—	—	—	—	—	—	—	—	52
—	—	—	—	—	—	—	—	—	54
—	—	—	—	—	—	—	—	—	58
—	—	—	—	—	—	—	—	—	59
—	—	—	—	—	—	—	—	—	60
—	—	—	—	—	—	—	—	—	61
—	—	—	—	—	—	—	—	—	63
—	—	—	—	—	—	—	—	—	64
—	—	—	—	—	—	—	—	—	65
—	—	—	—	—	—	—	—	—	69
—	—	—	—	—	—	—	—	—	70
—	—	—	—	—	—	—	—	—	73
—	—	—	—	—	—	—	—	—	74, 75
—	—	—	—	—	—	—	—	—	78
—	—	—	—	—	—	—	—	—	79
—	—	—	—	—	—	—	—	—	80
—	—	—	—	—	—	—	—	—	81
—	—	—	—	—	—	—	—	—	
27, . .	1886	800	No. 53 Jörgen, .	1890	750?	No. 67 Frejda, .	1894	1100	84
. . .	—	—	Do. . . .	—	—	No. 75 Mary, .	1895	1100	85
—	—	—	—	—	—	—	—	—	88
—	—	—	—	—	—	—	—	—	89
e ii, .	1892	750	No. 177, . .	1894	750	No. 177, . .	1899	1000	90
—	—	—	—	—	—	—	—	—	92
—	—	—	—	—	—	—	—	—	93
—	—	—	—	—	—	—	—	—	94
—	—	—	—	—	—	—	—	—	95
—	—	—	—	—	—	—	—	—	96
—	—	—	—	—	—	—	—	—	97
—	—	—	—	—	—	—	—	—	98
, .	1897	750?	—	—	—	—	—	—	99

For our present purpose there is no need to collect more figures. In the succeeding volumes, similar phenomena can be seen. Most often there is no serious difference between dam and daughter; but frequently they are widely apart, and the daughter is sometimes the better, sometimes the worse. If we look at the figures we see that they run in grades: the lowest being from 550 to 600, and the highest from 1,000 to 1,200; and we see also that a cow of either extreme grade never has a daughter belonging to the other. The daughters of extremes are either extremes of the same kind or are of a medium grade of from about 750 to 950. Again, the medium grade cows have daughters not only like themselves, but also of either extreme grade.

These phenomena suggest a Mendelian explanation, namely, that the extreme grades are the parent strains, and the intermediate the hybrid. If this suggestion be correct, then we ought to find three corresponding grades of bulls having daughters falling into similar grades according to the Mendelian formula.

The data founded upon this point are fewer than might be desired. They are sufficient, however, for the business in hand. Denmark is the place in which most data should have been found; but the Danish herd-books contain only a selection from their stock; consequently, it is difficult to find many bulls having more than a few daughters in the Herd-book. At home, again, few breeders have kept milk records long enough for our purpose, and still fewer have retained many daughters of the same bull till they were old enough to have several records kept. We have no other data meantime, however, and the choice lies between using such as we possess and waiting for more. The present inquiry may help to produce more. We shall give the Danish data first :—

Sires.	Dams.		Daughters.		Herd-Book Number showing data.
	Names.	Yields.	Names.	Yields.	
Max i. (born 1878),	No. 16,	650?	No. 21,	?	7
	No. 72,	600	No. 62,	750	42
	No. 21,	750	No. 104,	750?	43
	No. 28,	850	No. 64,	750	44
	No. 54,	750	No. 94,	750	45
	No. 19,	750	No. 102,	1100	46
	No. 91,	600	No. 83,	850	50
	No. 3.	700	No. 105,	750	51
	No. 1,	700	No. 55,	800?	52
	No. 54,	750	No. 94,	750	99
	Mörken,	?	Lone i,	800	171
	No. 43,	600?	No. 73,	800	196
	No. 61,	650	No. 98,	850	197
	No. 79,	550	No. 126,	750	198
Stamfadern (born 1885),	No. 64,	750	No. 91,	1000	44
	No. 94,	750	No. 111,	950	45
	No. 33,	750?	No. 1,	1000?	47
	No. 110,	750	No. 105,	750	51
	No. 55,	800?	No. 92,	1000	52
	No. 83,	850	No. 89.	800	194
	No. 62,	800	No. 86,	750	195
	No. 98,	850	No. 29,	850	197
	No. 126,	750	No. 43,	750?	198
	Ærespraemieko Lotte,	?	No. 7 Emma i.	950	237
	Ditto,	?	Thyra i,	900?	347
	No. 19,	750	No. 60,	950	273
Braendekilde Max (born 1886),	No. 62,	550	No. 39,	850	96
	No. 113,	750	No. 220,	1000	97
	No. 204,	750	No. 227,	950	98
	No. 94,	1000	No. 222,	1000	99
	No. 73,	800	No. 95,	800?	196

Sires.	Dams.		Daughters.		Herd-Book Number showing data.
	Names.	Yields.	Names	Yields.	
Vigfus (born 1888),	Munkebokoen,	?	No. 4 Damgaard,	950	24
	No. 10 Fut iii,	?	No. 5 Hanne,	1400	26
	Lörup i,	?	No. 1 Lörup ii,	1000?	147
	Dorthea,	?	No. 7 Fylla,	1050	217
	Do.	?	No. 58 Skov,	1000	369
	Gl. Grevinden,	?	No. 4 Grevinden i,	750	243
	Do.	?	No. 1 Ryslinge,	750	328
Osvald Ejersminde (born 1890),	No. 12 Lise i,	900	No. 4 Lise iii,	850	128
	Jenny ii,	1000	No. 8, Jenny v,	950	129
	No. 4 Lille Mörke,	950?	No. 5 Flora,	1100	203
	No. 1 Skrindshave,	1100	No. 6 Laura,	1000	204
	No. 1 Jenny i,	850	No. 18 Jenny iv,	850	280
	No. 2 Elna ii,	850	No. 3 Elna iii,	750	281
Gunnar (born 1891),	No. 1,	1000	No. 7,	1000	5
	No. 5 Laerken,	750?	No. 2 Sigrid,	850?	32
	Gamle No. 4,	?	No. 9,	800	53
	No. 1,	850?	No. 12,	850?	54
	Do.	?	No. 5,	850	55
	No. 1 Gl. Mutter	600?	No. 8 Hansine i,	650?	324
Mazeppa ii (born 1891),	No. 34,	900?	No. 17,	900	7
	No. 35,	850	No. 25,	1100	8
	No. 17 Else iii,	750?	No. 18 Else iv,	800?	37
	No. 1 Agnete,	850?	No. 9 Agnes,	1150	74
	No. 53 Jörgen,	750?	No. 75 Mary,	1150	85
	Lone i,	800	No. 12 Lone,	1100	171
	Gl. Rose,	?	No. 13 Rose i,	1000	172
	Do.	?	No. 2 Valborg,	900?	177
Tordenskjold (born 1892),	No. 11 Haarslev,	700?	No. 8 Haarslev v,	750	36
	No. 6 Gregor x,	650?	No. 15 Gregine,	950?	64
	No. 5 Lise,	900?	No. 1 Liseville,	1000	65
	Do.	900?	No. 8 Lisine,	900	221
	No. 1 Jomfruen,	700?	No. 7 Jomfrufine,	1000	222
	Odense,	?	No. 6 Odense,	1000	375

Sires.	Dams.		Daughters.		Herd-Book Number showing data.
	Names.	Yields.	Names.	Yields.	
Trym i (born 1893), .	No. 9 Agnes, . .	1150	No. 15 Thyra ii, . .	850	75
	Sognefoged Koen .	950	No. 1 Gine, . .	900	101
	No. 4 Johanna ii, .	1000	No. 12 Else, . .	1000	244
	No. 3 Petra, . .	700?	No. 13 Guldstjerne .	1000	256
	Jutta, ...	?	No. 5 Selma . .	1000	322
	Agnete i, . . .	850	No. 17 Agnete ii, .	1100	400
	No. 3 Ellen, . .	750	No. 5 Thyra, . .	650	410
Taurus iv (born 1894)	No. 5 Rebekka i. .	800	No. 48 Rebekka iv, .	1000	136
	No. 45 Palleshave ix, .	750	No. 18 Palleshave xiv,	1000	137
	No. 14 Laura iii, .	850	No. 51 Laura vii, .	850	138
	Do. . .	850	No. 31 Laura viii, .	1000	139
	No. 58 Laura v, . .	800	No. 20 Laura ix, .	850	140
	Do. . .	800	No. 5 Laura x, . .	800	288
	No. 4 Moer v, . .	?	No. 8 Moer x, . .	1000?	148
	No. 9 Gerda ii, . .	800	No. 15 Garda xi, . .	900	149
	No. 12 Martha v, .	800	No. 10 Martha vii, .	800	291
	No. 34 Mariane vii, .	800	No. 16 Mariane x, .	800	292
	No. 21 Kelros vi, .	800	No. 2 Kelros vii, .	850	302
	No. 55 Anne vii, .	550	No. 16 Ane ix, . .	750	335
	No. 32 Palleshave vi, .	650	No. 4 Lykke, . .	1000	383
	No. 57 Ryslinge viii, .	600	No. 4 Ryslinge, . .	750	413
Ambrosius iii . .	No. 3 Mads iii, . .	800	No. 12 Ambrosius ii, .	800	120
(born 1898), . .	No. 5 Karen, . .	1000	No. 2 Karen ii, . .	1000	254
	No. 13 Mester i, . .	800	No. 20 Thyra i, . .	750	372
	No. 2 Nybolls, . .	1000	No. 10 Karen, . .	1000	378
	No. 4 Ryslinge, . .	750	No. 21 Ryslinge, .	1000	413
	Söllinge i, . . .	750	No. 2 Söllinge iii, .	750	422

The above results come out according to the Mendelian formula, excepting that, although there a few third-grade dams there are no third grade daughters. The reason is that, in the herd-book from which these data have been taken there are very few third-grade cows entered which were born subsequent to 1880. These have been eliminated for breeding purposes by the best Danish breeders since about that time. Consequently, while we can say, from the yields of the dams and their daughters above, even though their numbers are small, that there are certainly first and second class red Danish bulls (for instance, Tordenskjold is probably first class, and Trym i. second), we can identify none that is third class.

At home we are little better off, since the best breeders usually get rid of their poor milkers as heifers after their first calf. Consequently, such records as would be got from the daughters of a third-class bull are few and incomplete. To overcome this lack of the ordinary data, however, we can fall back upon the observation made earlier in the paper, that a cow's daily yield at her maximum is an approximate indication of her total yield for a normal year. By so doing we can get more cases, since we catch poor heifers just after calving, or, at any rate, before they are got rid of. The method may not be absolutely reliable for some other purposes, but it is sufficient for the present, which is to determine whether sires fall into three grades like the cows, and breed accordingly. The difficulty in using the method is to determine exactly where the one grade of cow stops, and the other begins. There is this advantage, however, that there is no danger of putting a third-grade cow into the first, or a first into the third. Consequently, any errors in classification can have no vital effect on the general result. If, in herds containing all three grades of cows, we find bulls having only first- and second-grade daughters, others only second and third, and others all three grades, then we have identified all three grades of bulls. The case is parallel to that of the shorthorn colours. A red bull in a mixed herd of cows gets only red and roan calves; a white bull gets only roans and whites, and a roan bull gets all three colours.

In the following tables the progeny of five bulls used in the same herd of mixed cows are shown. It will be seen that there are all three grades among the five. Other cases have been found, but the numbers of progeny are smaller, and they need not be quoted. It should be noted that the herd in which these cases were found is not over-highly fed, and the pasture is moderate. Consequently, every grade is slightly lower in yield than the Danish cows were.

SIRE A'S DAUGHTERS.

Number.	Age.	Date of Calving.	Daily yields in lbs.		
			High Grade.	Medium Grade.	Low Grade.
1	3	September.	30	—	—
2	3	September.	—	25	—
3	3	August.	—	29	—
4	3	November.	30½	—	—
5	3	September.	32	—	—
6	3	December.	30	—	—
7	3	December.	35	—	—
8	3	November.	33	—	—
9	3½	December.	—	28½	—
10	2½	September.	31	—	—
11	3	September.	—	26	—
12	3	August.	—	24½	—
13	3	September.	31	—	—
14	3	August.	—	27	—
15	3	October.	—	28½	—
16	3	September.	—	26	—
17	3	September.	—	28	—
18	nearly 4	December.	—	28	—

This bull has no third-grade daughters, and is therefore a high-grade bull.

SIRE B'S DAUGHTERS.

Number.	Age	Date of Calving.	Daily yields in lbs.		
			High Grade.	Medium Grade.	Low Grade.
	2½	October.	—	22	—
2	3½	August.	—	25½	—
	3	December.	—	—	19
	2½	January.	—	23	—
5	3	August.	—	—	16½
6	3	August.	—	—	18
7	2½	September.	—	—	17
8	3	October.	—	—	18½
9	3	October.	—	22	—
10	2½	October.	—	22	—
11	2½	October.	—	—	14
12	3	October.	—	—	16
13	3	October.	—	23½	—
14	3	October.	—	—	13
15	3	October.	—	—	18½
16	3	November.	—	24	—
17	3	November.	—	27½	—
18	3	November.	—	21	—
19	3	November.	—	23	—
20	3	August.	—	23	—
21	2½	August.	—	—	16
22	3	August.	—	24	—
23	3½	September.	—	24	—
24	3	September.	—	28	—
25	3	September.	—	20	—
26	3	September.	—	21	—
27	4	September.	—	30	—
28	4	October.	—	33	—

This bull has no high-grade daughters, and is therefore a low-grade bull.

SIRE C'S DAUGHTERS.

Number.	Age.	Date of Calving.	Daily yields in lbs.		
			High Grade.	Medium Grade.	Low Grade.
1	2½	September.	—	24	—
2	2½	September.	—	23	—
3	2½	September.	28	—	—
4	2½	October.	—	23	—
5	3	October.	—	25	—
6	3	October.	—	27	—
7	3	November.	—	21	—
8	3	April.	—	—	22
9	3	June.	—	25	—
10	3	November.	—	—	15
11	3	November.	30	—	—
12	3	December.	35	—	—
13	3	September.	—	24	—
14	2½	September.	29	—	—
15	2½	October.	—	—	16
16	3	August.	—	21	—
17	3	September.	—	22	—
18	3	September.	—	23	—
19	3	September.	—	24	—
20	2½	June.	—	24	—
21	2¾	September.	—	23	—
22	2½	October.	—	22	—
23	3½	October.	—	23	—
24	2½	August.	32	—	—
25	2½	September.	—	23	—
26	2½	September.	—	24	—
27	2½	September.	—	25	—
28	2½	August.	—	26	—
29	3¼	August.	—	29	—
30	3	September.	33	—	—
31	3	September.	—	27	—
32	3	October.	—	—	18
33	3	November.	—	25	—
34	2½	October.	—	22	—

This bull has daughters of all three grades, and is therefore middle grade.

SIRE D'S DAUGHTERS.

Number.	Age.	Date of Calving.	Daily yields in lbs.		
			High Grade.	Middle Grade.	Low Grade.
1	2½	August.	—	—	10
2	3½	September.	—	—	20
3	3	September.	—	26	—
4	3	September.	—	25	—
5	2½	September.	—	—	17
6	2½	September.	30	—	—
7	3½	May.	—	26½	—
8	3	September.	—	25	—
9	3	September.	—	—	17
10	3	September.	—	21	—
11	3	September.	—	—	15½
12	3	October.	—	—	16
13	3	September.	—	22½	—
14	3	November.	—	25	—
15	3	January.	—	27½	—
16	3	June.	30	—	—
17	2½	September	—	22½	—
18	3	October.	—	—	14
19	2½	January.	—	20	—
20	2¾	November.	36	—	—
21	3	November.	—	21½	
22	3½	May.	35½	—	—

This bull has three grades of daughters and is medium class. There were in the herd daughters of this bull older than three years, and they belonged to the three classes.

SIRE E's DAUGHTERS.

Number.	Age.	Date of Calving.	Daily yields in lbs.		
			High Grade.	Medium Grade.	Low Grade.
1	2½	August.	—	20	—
2	3	August.	—	—	19
3	2½	August.	—	—	18
4	2½	September.	—	—	16
5	3	April.	—	26	—
6	3	May.	—	26	—
7	3	May.	—	26	—
8	3	May.	—	26	—
9	3	August.	—	22	—
10	2½	August.	—	22	—
11	3	August.	—	—	19
12	3	August.	—	21½	—
13	2½	September.	—	—	18
14	2½	September.	—	26½	—
15	2½	September.	—	21	—
16	2½	November.	—	25	—
17	3	November.	29½	—	—
18	2½	August.	—	—	18½
19	3	August.	—	26	—
20	3½	August.	34½	—	—
21	2½	June.	—	24½	—
22	2½	July.	35½	—	—

E has three grades of daughters, and is therefore himself middle-grade.

It ought to be mentioned that data similar to those found in the Danish herd-books have been found in the dairy herds belonging to Mr. L. A. Beamish, Ashgrove, Queenstown; Mr. John Evens, Burton, Lincoln; Messrs Hobbs & Sons, Kelmscott, Oxfordshire; and Mr. George Taylor, Cranford, Middlesex. Mr. Beamish's herd is a small one, consequently his numbers were small; and the three English breeders, like the Danes, have not been in the habit of retaining any poor-milking heifers that may have turned up in their herds till they made four or five records. Thus, since the figures got from these herds were merely a confirmation of the Danish ones, and, since their numbers as a whole were not essentially greater, it has not been thought necessary to publish them.

A few remarks by way of caution are necessary.

1. The whole of the foregoing data have been gathered from full-sized cattle: red Danish, shorthorns and shorthorn crosses. It may be that there are breeds in which there are fewer or even more general grades; but this is unlikely among British breeds, as all have had a very similar admixture by way of ancestry to those from which the data have been derived.

2. It is very probable that size plays a part in determining the yields of different grades. On this, however, we have had no evidence.

3. Although it has been possible to separate full sized cows into three general grades, it is possible, and even probable, that there are sub-grades within each, just as the red-and-white colour in cattle is a sub-grade of red, and just as among white cattle, there are pure whites, whites with red ears, and whites with black ears.

4. While examining many thousands of dairy cattle during the last five or six years, the question of external signs of yield was not considered definitely because it was assumed from the first that the usual signs relied upon are not reliable. But three things in the main have impressed themselves as being common to all good milking cows, viz.: a large and roomy udder, an excellent digestive capacity, and an absence of "patchiness," that is of accumulations of fat at the point of the hooks and elsewhere.

5. There are considerable variations in cows' yields, depending upon the way in which they are fed and cared for. A cow which may give 1000 gallons in one man's hands may drop to 700 or 800 in another's, and may rise even to 1100 in still another man's hands. This fact has to be reckoned with in estimating yields.

It need scarcely be pointed out that the writer of this paper realizes to the full that we are only beginning to understand how little we know about the cow and her yield, and how vast is the field of work yet before us. The

work represented by this paper can only be regarded as, in some degree, clearing the ground for the future.

In addition to the gentlemen mentioned in the body of the paper, there are many others to whom the writer is indebted for kindness and information. It is impossible to name them all, but he would wish to name specially Mr. Mansholt, of the Dutch Department of Agriculture; Dr. J. G. Rutherford, at Ottawa, and his assistants; Professor Wentworth, of the Iowa State College, Ames; Professor G. P. Grout, of the Minnesota experiment station, St. Paul; Governor Hoard, Fort Atkinson, Wisconsin; Mr. Robert Hobbs, Jr., Kelmscott; Mr. Howie, Secretary to the Ayrshire Milk Records Association; and the following Ayrshire breeders: Mr. Adam Montgomerie, Mr. Michael Logan, Mr. Thomas Clements, Mr. J. Moffat, Mr. W. H. Ralston, Mr. H. W. B. Crawford, and Mr. James Dunlop.

NOTE :—Throughout this paper yields have been expressed, according to the usual custom, in gallons rather than in pounds; and where pounds have been recorded in a herd-book or by a breeder, the figures have been divided by ten. This involves a slight inaccuracy. It raises British yields by about a thirty-third and depresses Danish by about an eleventh.

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VOLUME] XIII.

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