CHAPTER 30

Registering High Grades

For years after the registry associations were first organized, many of them admitted to registry grade animals with a certain number of topcrosses of registered sires. Nearly all of the American registry associations have ceased doing this, and most of those which register a breed native to other lands never did admit grades to registry in the United States. Most of the European breeds still register females having three or four top crosses of registered sires.[1] In most cases those breeds also practice selective registration (see chapter 16). The proposal is occasionally made that American breeds should also admit to registry high grades which are outstanding individuals.

The pure breeds of today are comparatively modern developments. Few have herdboks much more than 80 years old. Usually there was no official herdbook until years after the breed had really been formed. Naturally, at the time the herdbooks were established, the line between registered and other animals was somewhat arbitrary. Often there was disagreement as to whether certain animals really should have been included in the herdbook. With this background for the history of registration, the question automatically arises: What is wrong now with registering grades, when that was done in the founding of all breeds and still continues among many of them?

BREED HOMOZYGOSITY

The generations of strictly pure breeding that have elapsed since registration began have enabled the breeders to make the breed somewhat more homozygous than it was when the herdbooks were first closed. The amount of heterozygosity which was in the original foundation stock but which has been lost solely through the pure breeding since pedigree registration began can be measured by studying sample pedigrees of the breed at any desired date. Those figures for the breeds so far studied are as follows:

[1] For example, the Shire Horse Society in Britain admits mares with three topcrosses by registered Shire stallions. Volume 4 of their "Grading-Up Register" in 1944 contained the pedigrees of 49 mares with one topcross and 41 with two topcrosses, while 760 mares are entered in the contemporary Volume 64 of the regular Stud Book.

Shorthorn cattle in Great Britain	26.0% by 1920
Jersey cattle in Great Britain	3.9% by 1925
Ayrshire cattle in Great Britain	5.3% by 1927
Holstein-Friesian cattle in the United States	4.0% by 1931
Hereford cattle in the United States	8.1% by 1930
Brown Swiss cattle in the United States	3.8% by 1929
Aberdeen-Angus cattle in the United States	11.3% by 1939
Clydesdale horses in Great Britain	6.2% by 1925
Rambouillet sheep in the United States	5.5% by 1926
Hampshire sheep in the United States	2.9% by 1935
Poland-China hogs in the United States	9.8% by 1929
Brown Swiss cattle in Switzerland	1.0% by 1927
Landrace swine in Denmark	6.9% by 1930
Thoroughbred horse in the United States	8.4% by 1941
Standardbred horse in the United States	4.4% by 1940
American Saddle horse	3.2% by 1935
Telemark cattle in Norway	2.3% in 23 years

These figures are probably no more than .5 per cent above or below what would have been found if it had been possible to study the pedigrees of all the animals of the breed. Evidently pure breeding by itself causes only a slow drift toward homozygosity. The high figure for the Shorthorns was mostly incurred in the first 30 years, most of it while the breed was largely confined to the herds of the Colling brothers. For the other breeds it appears that about one-half of 1 per cent of the remaining heterozygosity is being lost per animal generation.

The figures given do not include any changes in heterozygosity which may have been caused by selecting animals which were more or less homozygous than their pedigrees indicate. Selection changes homozygosity only incidentally as a result of the changes it makes in gene frequency. Selection requires a long time to change q enough to make much change in $2q(1-q)$ except where the genetic situation is simple and selection is directed toward an extreme and the favored gene already has a frequency above .5. Selection may have increased materially the homozygosity of some genes which affect color, distinct anatomical peculiarities, and other details of breed type for which the genetic situation may be rather simple. But it is unlikely that selection has changed very much the average homozygosity of the breeds for genes affecting complicated characteristics. Selection for the effects of heterosis may even have operated in the other direction to hold the heterozygosity at a little higher figure than the pedigree studies indicate. It seems unlikely that selection can have had much net effect on the general homozygosity of the breed.

These considerations make it reasonably certain that the purebreds are more homozygous than the commercial stock, but doubtful that their difference in this respect is extreme, even allowing liberally for the fact that only a restricted group entered the registry in the first place. Grades having at least four topcrosses of registered blood would already be homozygous for about seven-eighths of the genes which were homozygous in that breed but rare in other animals. The admission of a few such grades would lower the breed's homozygosity very little.

INTRODUCING DESIRABLE GENES

Some grade individuals are much superior to the average of the purebreds in type or production or both. The best of these grades may possess desirable genes which are either unknown in the pure breed or are rare. The admission of these animals to registry might improve the pure breed through introducing or making more frequent such desirable genes. If females were required to have at least four topcrosses of registered sires in order to be registered, only about one-sixteenth of their genes would be other than those of the breed itself. This fraction would be further halved in their offspring. The frequency of genes already existing in the breed would not be changed much through the admission of such grades. If there are desirable genes which do not now occur at all within the pure breed, their introduction in this way might be important.

GRADES SHOULD MEET HIGH STANDARDS AS INDIVIDUALS

If the admission of grades is to improve the merit of the breed, the advantage from introducing desirable genes should be greater than the damage which would be done by upsetting the extra homozygosity which the breed has already obtained. Such safeguarding could be obtained by requiring the grade animal to meet distinctly higher standards of individuality and production than the average individual merit of the animals already registered. Just how much higher than the breed average these standards of individual merit should be for grades for which registry is being asked would depend in principle upon how different the pure breed really was from the foundation stock from which this grade was produced. Any standards adopted would necessarily be somewhat arbitrary.[2]

DISRUPTING EPISTATIC COMBINATIONS

It is possible that the present merit of the various pure breeds depends in part upon certain combinations of genes which produce good results as a combination but not separately. One such combination

[2] For an example of standards of this kind in actual operation in Sweden, see *Hoard's Dairyman*, 74:62.

might be typical of one breed (although of course not entirely homozygous in all animals of that breed), while very different combinations which have the same general kind of effect may be typical of other breeds. If so, the admission of even a little outside blood to the breed might scatter those epistatic combinations enough to lower merit more than the small percentage of outside blood admitted would indicate.

While this is theoretically a possibility, yet there seems no way to estimate whether such situations are frequent enough to be important. Even if such situations are frequent, grades carrying as many as four topcrosses of the pure breed would already have most of the genes which are necessary for such combinations. That makes the theoretical danger of harming the breed in this way seem rather remote. The existence of even a slight possibility of such damage is an additional reason for requiring that any grades to be admitted should meet standards of individual merit distinctly higher than the average of the pure breed into which they come.

ADMISSION OF PUREBREDS WHICH ARE NOT NOW ELIGIBLE TO REGISTRY

It often happens that a purebred animal cannot be registered because the breeder is not certain of its sire. The breeder may be certain that the sire of the animal was one of two or three males, all of which were purebred, but he may not have any record of the breeding date, or the actual birth date may be far from the expected one. Economical use of range resources often requires several males for each group of females. If the females are all purebred and the males are all purebred, all the offspring are purebred, too; but their individual pedigrees are not known and they are not at present eligible to registry in any association. Sometimes outstanding individuals are produced from such flocks or herds, and the breeder would like to use them for stud purposes if they could be registered. Several sheep associations in the United States have discussed proposals for such "flock registration," but none have been adopted. Such "flock registration" would not lower the homozygosity so far attained in the breed. A breeder using such animals could still use mass selection in improving his livestock but could not make much use of ancestors and collateral relatives to estimate breeding worth. Such a proposal might have unexpected consequences on the finances of the registry association, but that might be controlled by adjusting the fees for flock registration. Flock registration is a well established practice with sheep in many other lands, notably Australia.

ECONOMIC AND PSYCHOLOGICAL CONSEQUENCES

To admit high grades to registration might lower the breed reputation with those who set the highest value on absolute purity of breeding. This might be offset, at least in part, by the fact that some would construe such action to mean that individual merit was so highly respected in this breed that something in pedigree desirability would be sacrificed to attain unusual individual merit.

The registration of high grades would increase the supply of registered animals and, therefore, might tend to lower the prices which could otherwise be obtained by those who already have the purebred individuals. This could be controlled by having the requirements of individuality and productive ability so high that only a few grades would be admitted. Apparently this actually happens abroad. In most breeds where grades having at least four topcrosses of registered ancestry may be admitted to registry, only a small number are thus admitted each year. This slight increase in supply might be more than offset by an increased demand from those commercial producers who might be favorably impressed by the evident interest of that breed in individual merit. Just how those two factors would balance is not clear, but it seems unlikely that enough high grades would ever be admitted to registry to be an important economic factor.

Breeders would disagree about the wisdom of admitting any high grades at all to registration. If any breed does undertake such registration, it is likely that the official pedigrees will indicate which animals are absolutely purebred in all lines and which trace to some of those admitted high grades. Thus, the advocates of absolute purity could avoid pedigrees tracing in any line to the grades. Something of that kind actually happens unofficially in the case of pedigrees where there is suspicion but not absolute proof of fraud. Those who know the situation let such animals strictly alone, treating them as grades. There is thus a tendency to eliminate them from the breed, although a beginner unfamiliar with the situation will sometimes pay purebred prices for them. After many generations an official system of indicating those which trace at all to grades might break down with its own complexity; but long before that time had arrived, the breeders would either have revoked the registration of grades or would have come to substantial agreement that it was a sound policy.

SUMMARY

The registration of high grades unusually superior in individual merit is a common practice with many European breed associations but is practiced by very few associations in the United States.

The genetic consequences of such a practice are: (a) Some loss in homozygosity, and (b) the possibility of introducing some desirable genes which are rare or unknown in the pure breed.

If the grades were required to meet distinctly higher standards of individual merit and productivity than the average of the purebreds, the gain to the breed through the increase of desirable genes would be likely to be greater than the harm through loss of homozygosity.

Some animals which are absolutely purebred cannot now be registered because of uncertainty about which of two or more purebred animals was the sire. The admission of such animals to registry through a plan of "herd registration" or "flock registration" would not result in any loss of the breed's homozygosity. It might lead to a little breed improvement if only superior individuals were registered, although the selection of such superior individuals could be little more accurate than simple mass selection in general.

Economic reasons will predominate in decisions about the registration of grades. There might be some loss through the breed's appearing less strict in its standards of purity than its competitors. There might be some gain through advertising that individual merit was receiving special attention in that breed.

REFERENCES

For accounts of the increase in homozygosis in various breeds, see the references at the end of chapter 21. For other articles dealing more directly with the possibilities of registering high grades or with differences between grades and purebreeds, see the following:

Anonymous. 1927. A challenge to pure breeds. *Hoard's Dairyman,* 72:126–27. Feb. 10.
Anonymous. 1929. Admit grades to registry. *Hoard's Dairyman,* 74;637. July 10.
McDowell, J. C. 1928. Comparison of purebred and grade dairy cows. USDA, Cir. 26.
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CHAPTER 31

Sire Indexes

A sire index is a way of expressing what the sire's progeny indicate about his heredity. It is most needed for characteristics which the sire cannot show himself: milk and fat production in dairy cattle, egg production in poultry, prolificacy in swine and sheep, nursing ability in all mammals, and certain traits of disposition which are expressed differently in males and females,[1] etc. For characteristics which the sire can manifest in himself, a sire index is useful for revising estimates of his hereditary value when such estimates have been based only on his own characteristics and on his pedigree.

A complete sire index would logically be based on all available information about the sire's own characteristics and about his ancestors and collateral relatives, as well as on the information about his progeny; but most of the current discussion about sire indexes deals only with ways to use the information about the progeny and their other parents. Sire indexes of that kind are only special applications of the principle of the progeny test discussed in chapter 15. Sire indexes are mentioned most often in writings on dairy and poultry breeding.[2] Tbe wording used in the rest of this chapter applies primarily to dairy cattle. The principles are the same in other cases, but the importance of some of the considerations may change.

THEORETICAL BASIS

The reasons for computing a sire's index as $2D - M$, when D is the average of his daughters and M is the average of the dams of those daughters, may be seen from the equations on page 198. The reasons for not trusting the index completely arise from what are called "Mendelian errors" and "errors of appraisal" in those equations.

The Mendelian errors come from chance at segregation which permits gametes coming from the same parent to contain different genes, so that some offspring are genetically better than the average of their

[1] Hammond, John, 1932, *Report on Cattle-breeding in Jamaica and Trinidad*, Publication No. 58 of the Empire Marketing Board, London.

[2] See *Jour. of Dy. Sci.*, 16:501–22, for a discussion of the general principles involved.

parents while others are worse. These variations are truly random, provided the daughters are an unselected sample. Therefore, they tend to cancel each other and their importance in an average diminishes as the number of daughters increases.

The errors of appraisal come from the fact that even after we have corrected the record of a daughter or a dam for age, for times milked per day, and for every other non-standard environmental circumstance about which we know, the record will be higher in some cases and lower in others than corresponds to the real breeding value of the cow. Such of these errors as are random tend to diminish in importance as the number of daughters in the average increases, just as the Mendelian errors do. Some of the errors of appraisal are not random but tend to be in the same direction for all the daughters or for all the mates of the same bull but may be in a different direction or be different in size for the daughters or mates of other bulls. They may even be different for the daughters and for the mates of the same bull. Frequent causes of these biased errors are: (1) The general level of environment to which each group of daughters or of dams was exposed may have varied much from one group to another and we may not know what the environment was in each case, or may know it but not be able to allow perfectly for its effects. (2) The daughters or the records which were used to represent them may have been selected ones, rather than a fair sample of all. (3) The dams of these daughters may have been a selected group and the intensity of that selection, too, may have varied from one sire to another. Such biased errors do not tend to cancel each other as the number of daughters increases.

The actual numerical value of each sire index is partly determined by the real breeding value of the sire but partly also by whatever biased errors that index contains and by the uncanceled remainder of the random errors. Accordingly sire indexes will vary more than the real breeding values of the sires do. The sires with the very highest indexes are generally good sires but they are not likely to be as good as their indexes. Similarly the sires with low indexes are generally poor sires but they are not usually as poor as their indexes. We shall make the smallest mistakes if we estimate the breeding value of each sire at part way between his index and the average of his breed.

The principles governing how much confidence the index deserves can best be understood by considering first the dependability of an index (I) based on the record of only one daughter (D) and her dam (M). The variance of D and of M will be nearly the same. For clarity in the argument this variance can be divided into the additively genetic portion (G) plus a portion (E) due to random discrepancies between the genetic value and and the record of the cow, plus a portion (C) due to those discrepancies between record and breeding value which are alike for all the daughters of a bull or for all the mates of a bull. Then, according to the usual formula for the variance of a difference, the variance of the index is:

$$5G + 5C + 5E - 2G - 4xC = 3G + (5 - 4x)\,C + 5E$$

where x is the correlation between C for a daughter and C for her dam. The sire's breeding value is responsible for only G of the variance in this index, as may be seen by referring to diagram B in Figure 32. That diagram shows how the genetic value of an individual is $\frac{1}{4}$ determined by the genetic value of its sire, $\frac{1}{4}$ by the genetic value of its dam and $\frac{1}{2}$ by chance at Mendelian segregation.[3] The genetic variance which the dam determines is removed in subtracting M from $2D$. That leaves in the variance of I only $3G$ of the $4G$ which is the genetic variance in $2D$. The sire is responsible for $\frac{1}{3}$ of that $3G$, while chance at segregation is responsible for $2G$.

When the index is based on n daughter-dam pairs, instead of one, the random parts of the variance in I become only $1/n$ as large. Thus the variance of I based on n pairs is: $G + (5 - 4x)\,C + (2G + 5E)\,/n$. The equation which will predict with the least error the breeding value of the sire becomes:

$$\text{Sire} - A = \frac{n}{n[1 + (5 - 4x)\,C/G] + 2 + 5E/G}\,(I - A)$$

where A is the breed average. The fraction in this equation can be considered as showing the extent to which the index should be believed. The square root of this fraction is the correlation between the index and the real breeding value of a bull.

Wright has discussed this equation for the case of complete heritability; i.e., when C and E are both zero. Then it becomes simply: $\text{Sire} - A = \frac{n}{n+2}(I - A)$ and confidence in the index becomes almost complete when the number of daughter-dam pairs is much more than five. This, however, is not very realistic because in practice E will always be real and for many characteristics it will be much larger than G. C also is likely to have a real value in most sets of data which are collected from many herds, since it is rarely if ever possible to discount accurately for all of the differences in management and environment from one herd to another.

[3] If sire or dam were inbred, the fraction determined by the genetic value of that parent would be $\frac{1 + F}{4}$, while correspondingly less part would be determined by chance at segregation. In most populations inbreeding is unusual and is so mild that we can ignore it here with little error.

The effects of E may be seen most clearly by considering the case in which C is zero but heritability $\left(\text{i.e., } \frac{G}{G+E}\right)$ varies. Then the fraction in the prediction equation becomes: $\frac{n}{n+2+5E/G}$ which takes values such as the following:

Heritability	*Fraction*
.10	$\frac{n}{n+47}$
.20	$\frac{n}{n+22}$
.25	$\frac{n}{n+17}$
.33	$\frac{n}{n+12}$
.50	$\frac{n}{n+7}$
.71	$\frac{n}{n+4}$
1.00	$\frac{n}{n+2}$

If E is large the justifiable confidence in the index is obviously very low when n is small. Nevertheless perfect trust in the index is approached, although slowly, as n becomes extremely large.

The existence of C changes the situation so that confidence in the index increases more slowly with n and no longer approaches unity as a limit. Instead it approaches $1/y$ where $y = 1 + (5 - 4x)\, C/G$. This y can be a large number if C is large relative to G and if x is small. That C/G may often be as large as 1.0 in dairy data is indicated by correlation usually of the order of .2 to .3 between the records of unrelated or slightly related cows kept in the same herd. The general size of x is less certain. It would be 1.0 if all of C came from general differences in environment from herd to herd and if the peculiar environment of each herd were unchanging, year after year. However, part of C can come from herd environment which changes between the time when the dams made their records and the time when the daughters made theirs. A part of C can come from selection of the dams or of the daughters having been more intense for some bulls than for others. Hence x will not be 1.0 although it may usually be above .5. The case $C = G$ and $x = .5$, which is not unreasonable for dairy data, will illustrate the power of C to limit confidence in the index. In that case confidence in the index will not exceed $\frac{1}{4}$, even when the number of daughter-dam pairs becomes exceedingly large. If C is only half as large as G, the corresponding limit is $\frac{2}{5}$. If C is as large as G but $\frac{3}{4}$ of C is alike for the daughters and for the mates of the same bull, the limit is $\frac{1}{3}$.

Obviously anything which can be done to diminish C and E by keeping the environmental conditions standard and alike for all daughters and dams, or by correcting the actual records for the effects of varying environment or of unequal selection of the mates of various bulls will increase the confidence which the index deserves.

PRACTICAL CONSIDERATIONS

RELATIVE RATING. For comparing bulls with oue another when all of them have the same number of daughter-dam pairs, the index is all that is needed since it will then rank all the bulls in the same order and proportionately the same distance apart, no matter what is the value of C or E or x. The need for knowing how much to regress the indexes toward the breed average arises only when we wish to compare bulls proven on different numbers of pairs, or when we wish to compare a bull's index with a cow's record. For the first of these purposes ignorance of C, E, and x makes only a little difference unless n varies extremely from one sire to another. Doubling n will double the numerator but only the first part of the denominator. If that first part of the denominator is already more than half of it, the doubling of n will increase the fraction by less than one third of its initial value. Hence further increases in n when it is already large add only slightly to the confidence which the index deserves.

COMPARING BULLS' INDEXES WITH COWS' RECORDS. The necessity for comparing a bull's index with the records of a cow is met almost every time we evaluate a pedigree in which the sire or one or both grandsires are proven. For example, in choosing between young bulls A and B we may find that the sire of A has an index which is 40 pounds higher than the index of B's sire but that the records of B's dam average 60 pounds higher than the records of A's dam. To estimate whether A or B probably has the higher breeding value, we have to decide whether a difference of 40 pounds in sire indexes is as important as a difference of 60 pounds in the records of cows. If the cow's record is left in its actual form, sire indexes can be compared directly and fairly with it if the indexes have been regressed only enough that they would have about the same variability as the cows' records—a little more variability if an index is generally a bit more accurate as an indicator of a sire's breeding value than a cow's record is of her breeding value, but a little less variability if the indexes are generally less accurate. If the indexes are regressed as far toward the breed average as they should be to make each numerically equal to the estimated breeding values of the bull to whom it belongs, then the cow's record also should be regressed far enough toward the breed average to make it likewise an unbiased estimate of her breeding value. Present practice in this respect is not uniform. The Holstein-Friesian Association publishes indexes based on six or more pairs and does not regress them at all. This makes these indexes just a bit more variable than the records of cows with one record each. The same is true of the indexes computed by the American Dairy Cattle Club from the records published by the Dairy Bureau of the USDA, except that in this case the minimum number of pairs is five. The Ayrshire Association since late 1944 has been regressing sire indexes half way toward the breed average and basing them on at least ten pairs. Sire indexes regressed this much are only about half as variable as records of cows who have one lactation each.

NUMBER OF DAUGHTER-DAM PAIRS NEEDED. From the principles governing the accuracy of sire indexes it is clear that accuracy is low when the number of pairs is very small but it is also clear that accuracy does not suddenly become perfect when a certain number is reached. Instead the accuracy increases at an ever-decreasing rate as the number rises. Since the gain from increasing n comes solely from the decrease which that makes in the term $(2G + 5E)/n$ in the variance of I, the advantages in having n any larger have mostly been reaped by the time $(2G+5E)/n$ has already become distinctly smaller than $G + (5-4x)C$.

Largely by trial and error but partly based on considerations like these, all official plans for computing indexes specify some minimum number for n before an index will be computed at all. One important consideration which has kept the minimum numbers small is that if many daughters were required few bulls could be proved. Those who made the Dairy Bureau policy thought that the increased accuracy which the proof would have, if six were required instead of five, would be more than offset by the fact that the large number of bulls who have only five comparisons would thereby not be brought to the attention of breeders who might otherwise hear of them and make some use of that information. There is good reason for believing this still to be sound policy, although the original decision was made years ago. One suggestion for reaping both advantages is that bulls be given a preliminary index when five pairs are available and another index when the number has risen to another level, for example eight or ten. The Ayrshire Association does something of this kind. This, however, adds to the bookkeeping and some customers will not distinguish between the bulls with only preliminary proof and the bulls with more complete proof.

Simplicity of the index is important for explaining it to the potential users and giving them the proper amount of confidence in it, for ease and speed of computing it, and to reduce the chance of clerical errors. Yet the underlying principles are such that at least a little accuracy must be sacrificed if simplicity is to be achieved in data in which n varies or if the same index is to be used in different populations, such as Dairy Herd Improvement Associations or Herd Improvement Registry, in which the relative proportions of G, C and E may vary. When breed associations or other agencies compute and publish indexes as an impartial service to buyers, they have to compromise a little on accuracy in order to achieve the uniformity and simplicity which is necessary for getting the index used. Whether it is better merely to publish $2D$-M and let the user do all the discounting of this for C, E and small n; or to regress it automatically half way toward the breed average as the Ayrshire Association is now doing, or to regress it some other fraction (perhaps one fraction for test, a different one for fat, another for type, etc.), is still open to argument. The issues involved are largely psychological ones centering on what procedure actually will get most breeders to use the indexes with most nearly the proper degree of confidence and with the least confusion and disappointment.

Selection of daughters will bias the index to an extent for which good correction can be made only in the unlikely event that one knows how intense the selection was and on what it was based. If the number tested but omitted from the average is known, it can be assumed that the missing ones had lower records than any of those given. For example, if we read that a bull had 10 daughters which averaged 600 pounds in a Dairy Herd Improvement Association but we happen to know that ten other daughters of his were tested, we can see by Table 12 that the high half of a normal distribution averages .8 of a standard deviation above the average of the whole group. With the intra-herd standard deviation in such data being around 80 pounds of fat, we can estimate that the average of all 20 daughters was about 600 minus 64 or 536 pounds, but that could easily be 30 or more pounds in error with numbers this small and with the distribution perhaps not being exactly normal. As another example, suppose we are told that a certain bull has 30 Advanced Registry daughters, five of which have records over 800 pounds. It is safe to assume that these five are the very highest. By consulting appropriate tables for the normal curve we learn that the point above which the highest one-sixth of the population lies is about one standard deviation above the average of the whole group. Since the intra-herd standard deviation in Advanced Registry data is about 100 pounds, we would estimate that the average of all 30 daughters was about 700 pounds, hut this could be considerably in error, especially since the numbers are small and the distribution of Advanced Registry data is not quite symmetrical.

If the missing daughters were not even tested, corrections for their absence are even more in doubt since one cannot then assume that their average would have been low. Some may have died while yet young, some may have been culled intentionally on type or pedigree, some may have been sold into herds in which no testing was done, some may have been started on test and then removed (in the testing plans which permit that) when it was seen that they would do poorly, etc.

Considerations such as these have led breed associations to compute indexes only with data from those systems of testing in which it is required that all animals in the herd be tested if any are. Also it is only reasonable for such agencies to inquire about the missing daughters. Some associations are not able to do more abont this than to publish, along with the average of the tested daughters, the total number of daughters old enough to have had a record. This can give the reader some notion of how much possibility there was for selection among the daughters of each sire.

There is no way wholly to avoid natural selection among the daughters. More of the constitutionally weak or sickly daughters than of the normally healthy ones will be barren or will have died before they could be tested. Also it is to the immediate economic interest of the breeder to cull the extremely unpromising heifers as soon as he knows they are such, without incurring the expense of keeping them through their first lactation. However, the correlation of outward appearance or pedigree promise with actual performance is low enough that the effects of such culling prior to testing are much smaller than the effects of omitting daughters after their records are already partly made. It has been proposed but never officially adopted that in proving a sire each daughter old enough to have a record, but without one and without a satisfactory excuse, should be arbitrarily assigned a record well below the breed average. This would increase the pressure on the breeders to get all the daughters tested, but most responsible breeders have thought it too drastic for adoption.

SELECTED DAMS. When the dams are a selected sample of their generation, their breeding values will generally average below their records, especially if the selection was primarily on their own records. Most voluntary culling of dairy cows is done during their first or second lactations. The more calves a cow has, the more chance she has of appearing as a dam because a daughter was reared and tested. The dams will therefore consist largely of cows which have survived several cullings. M will generally be a bit farther above the average breeding value of the dams, than D is above the real average breeding value of the daughters.

If this bias were of the same size for all bulls it would not matter when comparing one bull with another. It would merely make all of them appear a little lower in breeding value than they actually were. But when one bull is mated to a highly selected set of dams while another is mated to a group of dams scarcely selected at all, then subtracting M from $2D$ makes the bull mated to the more highly selected group of cows appear poorer than he actually is. Reasonably good correction for the effects of selecting the dams can be made by using only records which the dams made subsequent to their selection, or by regressing their records toward their contemporary herd average as was indicated in chapter 13, but often the data are not assembled conveniently for doing that.

MISSING DAMS. Since testing is not universal and is not always continuous within a herd, some of the daughters of a bull may have records, while their dams do not. In such cases the best procedure is generally to use in place of M for each missing dam the average record of the herd contemporary with the daughter or, if that is not available, to assume that the missing record was equal to the average record of the other dams. There is, of course, some possibility of introducing errors by this, but generally the errors thus introduced would be smaller than those which can be removed by utilizing the record of this daughter corrected thus for the average effects of the herd environment.

DIFFERENCES IN GENERAL ENVIRONMENT FROM ONE HERD TO ANOTHER are of considerable importance in dairy data, as is evidenced by a correlation usually around .2 to .3 between the records of unrelated cows in the same herd. When daughters and dams are in the same herd, as is usually the case, whatever is peculiar to that herd will tend to push the records of both in the same direction. Doubling the daughter's record and subtracting the dam's record automatically takes from the doubled record of the daughter one half of the effect which the herd environment produced on it, to the extent that environment was alike for daughter and dam.

Two devices for removing from the index the remaining error from herd-to-herd differences in environment deserve mention. First, the prospective purchaser should study the conditions of that herd and discount the effects of conditions which were not standard. This he can never do perfectly but he can often do enough to make it worth while to visit the farm, to inspect the feeding practices, examine the record books, etc.

The other device is the statistical one of considering each cow's record partly on its own absolute value and partly on the difference between it and the average of the herd at the time it was made. To go to the extreme in this direction and judge a cow entirely on her deviation from the average of her herd is equivalent to assuming that all the differences between herd averages are environmental and that all herds are equal in average real producing ability of the cows. To go to the other extreme and not to consider the herd average at all is to assume that there are no differences in environment from one herd to another. The truth is somewhere between these extremes. In principle it is clear that the cow should be judged partly on the absolute size of her record and partly on its deviations on the herd average. The practical problem is to know how much emphasis to place on each. The principles governing this were outlined in chapter 24 on the family structure of populations. Consider each herd as a family. The phenotypic correlation between herd mates (t in the formulas in chapter 24) is usually something like .2 to .3 but if desired, may be determined more exactly for the population in question by examining the data pertaining to that. To determine the genetic resemblance between members of a herd (r in chapter 24) will require some study of pedigrees. Also there may be some doubt about how much genetic resemblance has been introduced by assortive mating or by differences in intensity of selection which will not show in the pedigrees. Probably the intra-breed genetic resemblance between herd mates is usually something like .10 to .15 in small dairy herds in which nearly all of the females were born in the herd. With $r = .10$ and $t = .20$ an average rough correction for the general effects of herd environment could be made by subtracting from the index half of the difference between the average of the herd in which it was made and the general average of all herds in that population. More should be subtracted if t is higher and less if r is higher. This cannot be highly accurate in individual cases, since some herd averages are high mostly for environmental reasons while others are high mostly for genetic reasons. Some such use of the herd average (perhaps with a fraction larger or smaller than one-half) appears likely to remove more errors than it introduces, but it has not yet been tested extensively enough to learn all its actual advantages and disadvantages.

To correct for differences in environment from region to region, especially for the effects of altitude, so that sires in different regions might be fairly compared with each other, Engeler in Switzerland proposed to use the differences between the average of the bull's daughters and the average of the association in which those daughters were tested. This proposal has several practical advantages where environmental conditions are rather uniform within each locality but vary widely from one locality to another. Daughters out of untested dams can be used. The association average is based on so many records that there is little random error left in it. This method would hardly be suitable for data in which environmental conditions varied widely from one herd to another within the same locality. It neglects differences between the average breeding value of the mates of one bull and the average breeding value of the cows in the whole association but perhaps those are not often large. As an example of his method Engeler gives as proof for the bull Zamboli:

the bull Zamboli:	Milk	Test	Fat
Six daughters with 17 records average. .	3,725 kg.	3.82%	142 kg.
The association average (150 records) . .	3,556 kg.	3.86%	137 kg.
Difference	+169	—.04	+ 5

Dams and daughters treated differently. It is always possible that the dams were treated differently from the daughters. This is especially likely to have happened when the dams were tested in one herd and the daughters in another, or when the dams were tested at a much earlier date than the daughters. Such a difference in general treatment lowers x in the preceding formulas and thereby decreases the confidence which the index deserves. The available remedies for this are only the same two mentioned previously; namely, to examine the conditions under which the dams and the daughters made their records and to correct as best one can for the effects which such conditions had on the records or to make more use of the average of their contemporary herd mates.

Indexes for dams could be constructed also. The general principle would be similar to that of diallel crossing. The breeding value of the dam would be estimated to be twice as far above the average of the other mates of the sire as her own offspring were above his other offspring. Of course one would trust such an index only a little, since one dam can have only a few offspring. Such a dam's index should be regressed far toward the average of the breed in order to get an estimate of her breeding value which is as likely to be too high as too low. If heritability is high such an index would be trusted considerably but in that case there would be little need for an index, since the dam's own phenotype would be a rather good guide to her breeding value. If heritability of the characteristic is low, the evidence from the index would be needed more but the low heritability and the small number of offspring would require that it be discounted considerably.

Indexes for other characteristics. Sire indexes can be constructed for other characteristics, just as well as for milk and fat production, if those characteristics are measured or scored definitely enough that the daughters can be averaged into a single figure and also that their dams can be averaged into a single figure. Indexes need not be confined to characteristics which are manifested in only one sex, although they are most needed and useful for those. For example an index could be applied to transmitting ability for type as well as for production. It would only be necessary that the type of the offspring and of the mates be scored, classified or otherwise graded in numerical terms so that these ratings could be averaged. Naturally, the proper amount to trust the index is not likely to be the same for all characteristics, since the relative sizes of G, C and E and the size of x will not be the same for all.

COMPARISON WITH OTHER WAYS OF PROVING SIRES. The average of all daughters without any attention to their dams is sometimes used as the proof of a sire. For example, this is the present practice of the American Jersey Cattle Club. Sometimes the increase of the daughters over their dams is used as the proof. The index is simply the sum of the daughter average and the daughter-dam difference. Therefore it partakes of the errors of each and tends to be midway between them with respect to vulnerability to different kinds of errors except where those errors bias the daughter average and the daughter-dam difference in opposite directions. In such respects the index is more accurate than either. An example is the errors introduced by unequal selection of mates. Such selection makes the daughter average too favorable and the daughter-dam difference too unfavorable toward the bull mated to the highly selected groups.

The relative accuracy of the three measures of a bull is determined mostly by the size of r_{DM}, the correlation between the average of the mates and the average of the daughters of the same sire. When r_{DM} is less than .25 the daughter average is the most accurate of the three. It remains more accurate than the daughter-dam difference as long as r_{DM} is less than .5. The index is more accurate than the daughter average when r_{DM} exceeds .25 and is more accurate than the daughter-dam difference until r_{DM} exceeds .75. In most dairy data r_{DM} is around .55 to .65. When it is exactly .6 the relative accuracy of daughter average, daughter-dam difference, and index is 1.00 : 1.12 : 1.24.[4] The daughter average is simpler to compute, since there is no need even to know

[4] This assumes that M is as variable as D and that the genetic value of the sire is not correlated with the records of his mates. The first assumption is very nearly true in dairy data. Moderate deviations from it will not alter this ratio much anyhow. The second assumption will be very nearly true in all populations unless there is enough inbreeding to make considerable separation into unrelated lines or unless there is a strong degree of assortive mating because breeders differ widely in their ideals and in the intensity of their striving.

the records of the dams. Whether this saving in computation costs is enough to offset the lessened accuracy depends, of course, on the amount of that saving and on what use would be made of the greater accuracy if it were available.

COMBINING INDEXES WITH OTHER INFORMATION. The sole purpose of a sire index is to estimate the breeding value of the sire. An ideal sire index would pay some attention to the records of the bull's dam, sisters, and more remote relatives, instead of being based solely on his daughter and their dams. To some extent these various relatives duplicate each other in the information they offer. They vary in their relationship to the bull and in the number of records each has. No simple and general formula has been devised to fit all the possible combinations of this. Records of the bull's dam and of his full sisters can be combined into a single estimate according to the following formula from Wright: Sire $= \frac{A}{m+1} + \frac{m}{m+1} R$ where A is the breed average and R is the average production of his dam and m - 1 full sisters. This however is based on the supposition of complete heritability. When heritability is less than complete, R would be given less attention and A would receive more attention than this formula shows. Few dairy bulls have as many as two tested full sisters.

If a bull has many more than three daughters his index will naturally receive more attention than his pedigree but his pedigree still contains some information which ought not to be neglected entirely.

Not often will a sire index indicate a bull's inheritance more accurately than the available information will indicate the inheritance of a cow tested in two or more lactations. That will depend mainly on how little the records of the bull's daughters contain of the effects of nonstandard herd environment; that is, of what is called C in the preceding formulas.

The sire index can be useful in pedigrees by indicating which young bulls are most likely to be worth trying as sires. For example, consider the pedigree of the bull X, itself too young to be proved but sired by a bull with an index of 700 pounds of fat and out of a cow whose records averaged 500 pounds but whose sire had an index of 800 pounds and whose dam's records average 400 pounds.

$$X \begin{cases} A \text{ (700 lb. index)} \\ B \text{ (500 lb. record)} \begin{cases} C \text{ (800 lb. index)} \\ D \text{ (400 lb. record)} \end{cases} \end{cases}$$

We would estimate X at $\frac{700}{2} + \frac{500}{2}$, or 600 pounds, modified, of course, by whatever allowance toward the breed average we think is necessary on account of our not being sure that the information about *A* and *B* is exactly equal to their breeding values. If *B*'s records are few or made under uncertain circumstances, we will have less faith in them and will examine her pedigree. That indicates that she was expected to produce $\frac{800}{2} + \frac{400}{2}$, or 600, instead of the 500 she actually produced. Hence, we will suspect that she really has a little better heredity than her own record indicates. We will not be certain of that because we are not entirely certain of the breeding values of *C* and of *D* and because all animals are so heterozygous that such a mating as that of *C* and *D* might produce an individual much poorer or better than is expected. The amount of attention we give to *C* and *D* will depend mainly on how uncertain we are that the 500-pound figure correctly represents *B*'s inheritance. If *B* were never tested—for example, if *X* were her first calf and she had died soon after calving—we would estimate *X* at $\frac{700}{2} + \frac{800}{4} + \frac{400}{4}$, or 650 pounds, modified by some allowance toward the breed average; but we would be more uncertain about our estimate than if *B* had been tested.

SUMMARY

A sire index is a means of expressing in a single figure a sire's progeny test, usually for characteristics he cannot express himself. It is most frequently used for dairy bulls and for roosters.

The index which seems most useful and accurate under many conditions is the average of his daughters plus the average increase of the daughters over their dams.

The daughter average and the difference between daughters and dams are the parts of which the index is the sum. The daughter average is most vulnerable to error from differences in environment from herd to herd. The difference between daughters and dams is most vulnerable to error from environment's not having been the same for daughters and dams or from the dams' having been selected more highly than is fully discounted. The difference between daughters and dams is least subject to error from variations in environment from one herd to another. The index is a better guide to the sire's breeding value than the daughter average or the daughter-dam difference when the correlation between daughter average and average of dams is more than .25 but less than .75.

Some room should still be left for considering the production of ancestors and collateral relatives, even when a bull has many daughters.

An index cannot be guaranteed correct, since indexes will often contain considerable error from Mendelian sampling and from incomplete corrections for other circumstances. Hence a sire should be estimated nearer the average of the breed than his index is, especially if his index is extremely high or extremely low.

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CHAPTER 32

Bull Associations or Bull Circles

The bull circle is a co-operative plan by which dairymen exchange sires at regular intervals.[1] In the association there are at least three, and usually not more than five, blocks or stations. One bull is purchased for each block or station. A block may consist of a single large herd, or it may be a group of several small herds so located that one bull can be used for all. After the bulls have been in service two years, they are moved to another block. At the end of the second two years they are moved to a third block. If there are more than three blocks in the circle, the bulls may be moved at the end of six years to a fourth block, where they have not been in service. If there are only three blocks in the circle and a bull is still alive and capable of service at the end of six years, he may be brought back to the block where he was first used. By that time he will have been thoroughly proved. If he proved to be a very good bull, it will be wise to use him even on those of his daughters which are still in the first herd. If he turned out to be only an ordinary or an inferior bull, he will be sold to the butcher. In most cases he will have died or become sterile before he has completed six years of service. Only rarely will the question arise as to the desirability of breeding one of those bulls to his own daughters.

OBJECTS

The primary object of a bull circle is to get bull service at lower cost, or better bull service at the same cost, without running any risks from inbreeding. If three men co-operate in a three-block circle, each will at all times own one-third of three bulls instead of each owning one bull. Except for death and sterility, each man will get six years of

[1] The intervals are usually two years in length, which is about as long as they can well be without occasionally breeding some sire to his own daughters. Sometimes the intervals are as short as one year in order that the different owners may get more nearly the same amount of service from each bull. The shorter interval tends to equalize among the circle members the differences between the bulls, but it incurs the bother of the exchange more frequently and increases the opportunities for spreading breeding diseases. This chapter assumes that the exchanges will take place at intervals of two years; but, if a few words are altered, the discussion will apply as well to cases where the exchanges are more frequent.

bull service instead of two for the purchase price of one bull. A breeder can spend less money per year in purchasing bulls even though he may spend more money for each bull he does buy in order to get a better pedigree or individual.

Another object is to keep dairy bulls alive until they are proved in order that the unusually good ones among them can be used extensively after the evidence proves them. Two years after a bull first begins his service, his oldest daughters will be approaching 15 months of age and will be ready to breed. At the end of four years of service his very oldest daughters may have completed one lactation; bnt unless he had many daughters from his very first services, he will be only partially proved when it is time to move him to the third herd. Before it is time to move him to the fourth herd he should be thoroughly proved. If he is proved inferior, he will, of course, be sent to the butcher and his least productive daughters will follow him. If he is proved only mediocre, he is apt to go to the block also, since his age increases the probability that he will soon become useless for breeding. If he proves to be very valuable, he can be returned to the first herd for use on his own daughters and granddaughters, thus making possible some intense linebreeding to him.

The bull-circle plan makes it easy to pursue a consistent linebreeding policy. For example, the first bulls in a four-block circle may all be half brothers by some famous bull. The continued use of these bulls on each other's daughters would tend toward producing herds which would be almost as closely related to this outstanding sire as if they were daughters, although it might have been quite impossible financially to buy actual daughters of that noted bull. The amount of inbreeding in such a plan would never get very high, tending toward but never reaching 12½ per cent; and all of it would be directed toward the famous bull. If the cows in these herds are purebred, and one of the sires used proves to be an unusually good one, it would be practical to choose the next bulls out of the best cows in those herds where the best sire had been used. This would lead to still further linebreeding, but with four or five blocks in the bull circle it is unlikely that this linebreeding could rise high enough to be dangerous, even in 30 or 40 years of steady co-operation, provided care was always taken to select the sires from the best cows in the herd, sired by the best of the preceding bulls. In short, the bull circle offers almost an ideal plan for linebreeding which is fast enough to make progress but not fast enough to be dangerous.

The bull-circle plan may also assist in a less tangible way through the development of community spirit and co-operation. Naturally the members of the bull circle will need to be members of a cow-testing association if they are to take advantage of any of the objects of the bull circle other than that of the cheaper bull service.

A "bull club" is merely the joining of several men together in the co-operative purchase of a single bull. This lowers the bull cost to each of them but does not lead to the proving of the sire since, after he has been used two years, they will need to exchange him if he is not to be bred to his own daughters.

INTENSITY OF INBREEDING BROUGHT ABOUT BY BULL CIRCLES

The upper part of Figure 48 shows a pedigree with the most extreme inbreeding which could be produced in a five-block bull circle, where the five bulls first bought were all half brothers and each saw service in all five blocks. A bull would rarely remain in service that long. Variations in the sex ratio would make exceedingly rare a succession of daughters which would result in a pedigree like this one, where *X* is a descendant of all five bulls.

The lower part of Figure 48 shows some examples of the most extreme inbreeding which would be apt to result in a three-block circle where all three bulls were half brothers at the start, were used for six years, and then it was discovered that one of them was so outstanding that he would be used again. He would go back for service again in the herd where he had first been used and would be mated to some of his daughters, granddaughters and great granddaughters. There would not be many of each. Sons of his would be placed in service in the other two herds, where they would be used on some cows which were their paternal half sisters and on others which were their cousins through the paternal grandsire. The total amount of inbreeding in 10 or 12 years of such a plan is not likely to go above 25 per cent in any individual and probably would average only about 8 or 10 per cent. Moreover, this inbreeding would nearly all be toward the famous sire, *Y*, or his best son, *E*.

BUSINESS PRECAUTIONS ADVISABLE

The title to the bull should rest in the bull association rather than in the individual members. If each man owns one bull it is almost certain to happen that, by the time the bulls are mature, some of them will appear to be better individuals than others, and the owners of those will be reluctant to exchange. If each man owns his share of all bulls, there will not be as much of this difficulty.

A reserve fund should be provided for the replacement of bulls which die or become sterile or which eventually prove themselves to have been only average or less. An assessment of each block might be

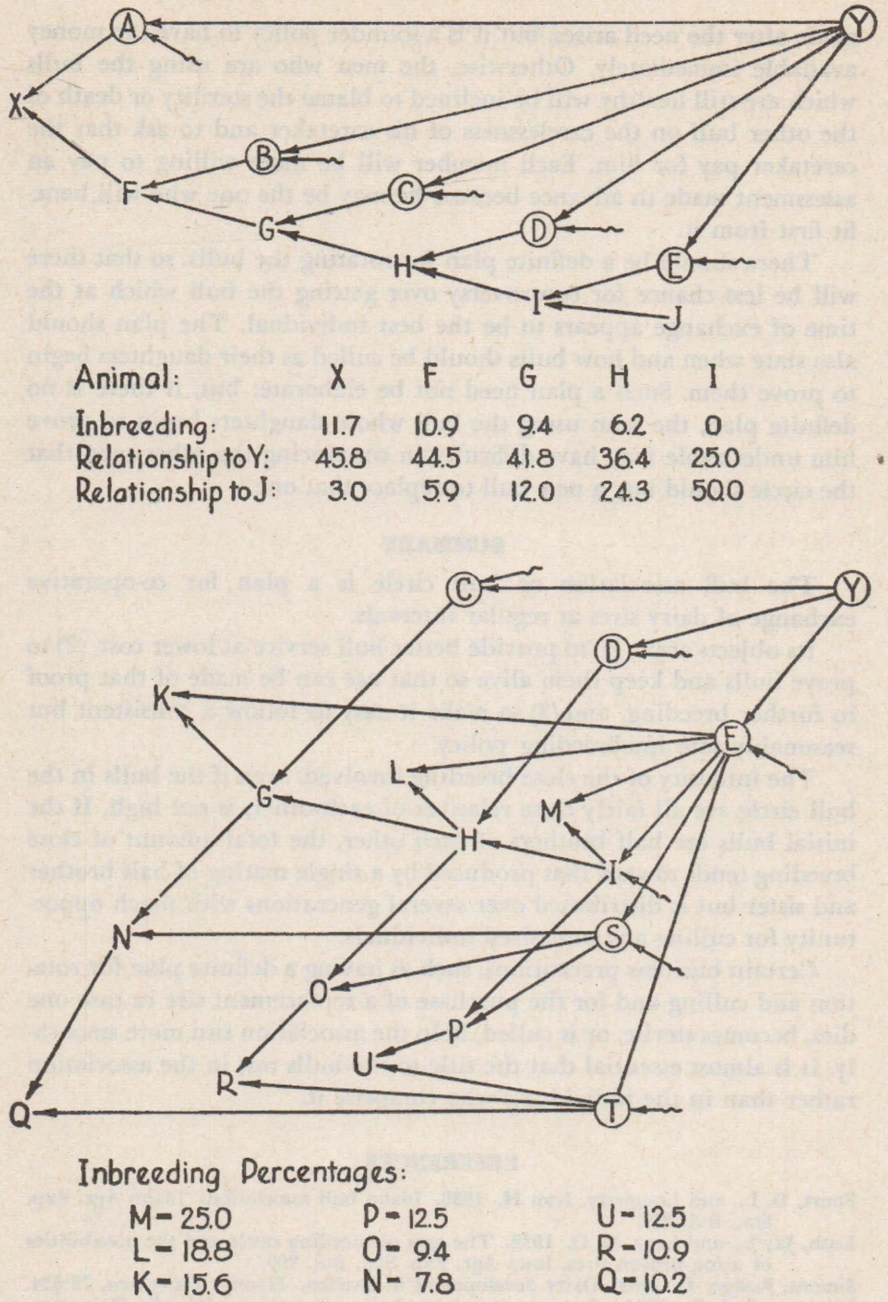

FIG. 48. Some examples of extreme inbreeding which might happen in a bull circle where the bulls were paternal half brothers. Upper: In a five-block circle where no bull ever returned to the same block and the linebreeding is purely to Y. Lower: In a three-block circle where the linebreeding is first to Y and then to his son, E, who is returned to be used a second time in the circle in rotation with two of his sons, S and T. Encircled letters indicate sires.

made after the need arises, but it is a sounder policy to have the money available immediately. Otherwise, the men who are using the bulls which are still healthy will be inclined to blame the sterility or death of the other bull on the carelessness of his caretaker and to ask that the caretaker pay for him. Each member will be more willing to pay an assessment made in advance because he may be the one who will benefit first from it.

There should be a definite plan for rotating the bulls, so that there will be less chance for controversy over getting the bull which at the time of exchange appears to be the best individual. The plan should also state when and how bulls should be culled as their daughters begin to prove them. Such a plan need not be elaborate; but, if there is no definite plan, the man using the bull whose daughters begin to prove him undesirable may have difficulty in convincing the other men that the circle should buy a new bull to replace that one.

SUMMARY

The bull association or bull circle is a plan for co-operative exchange of dairy sires at regular intervals.

Its objects are: (1) to provide better bull service at lower cost, (2) to prove bulls and keep them alive so that use can be made of that proof in further breeding, and (3) to make it easy to follow a consistent but reasonably safe linebreeding policy.

The intensity of the close breeding involved, even if the bulls in the bull circle are all fairly close relatives of each other, is not high. If the initial bulls are half brothers of each other, the total amount of close breeding tends toward that produced by a single mating of half brother and sister but is distributed over several generations with much opportunity for culling any undesired individuals.

Certain business precautions, such as having a definite plan for rotation and culling and for the purchase of a replacement sire in case one dies, becomes sterile, or is culled, help the association run more smoothly. It is almost essential that the title to the bulls rest in the association rather than in the individuals who comprise it.

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CHAPTER 33

Community Breeding

Most breeds of livestock arose from community breeding in a small region where a few herds located conveniently to each other exchanged breeding stock during the formative period of the breed and really established the breed by linebreeding to the best individuals within those herds. Community breeding became less typical when herdbooks were established and men unfamiliar with each other's stock could still work with the same breed.

Community breeding has not been general in the United States, although at one time the Poland-China breed was a community breed in Butler and Warren Counties in Ohio. Likewise, the Chester-White was long a community breed in Pennsylvania, although the details of that history were not kept. A few other prominent breeds for at least short periods have been community breeds in America before they expanded to nationwide importance. Spread over a vast territory, with breed organizations endeavoring to expand their spheres of influence, and with high-pressure salesmanship often working most effectively on prospects who are at some distance from the herds where the animals are bred, the prominent breeds in America have generally been far from any condition which could be called community breeding. Among scattered examples which approached the condition of community breeding in America should be mentioned the Vermont Merinos, light horses in the Bluegrass region of Kentucky, the New Salem (North Dakota) Breeding Circuit for Holstein-Friesians, and county associations such as the Delaware County (Ohio) Percheron Breeders' Association and some of the county associations of dairy breeders in Wisconsin.

Many writers on animal breeding subjects have emphasized the advantages of community breeding, but this seems to have had little effect on general practice. In many communities even yet a man beginning to breed purebred livestock will deliberately select a breed which is not present or at least is not abundant in his community, thinking that he will thereby have less competition and a better chance to make his herd well known than if he started with a breed already well established in that community.

MORE ACCURATE CHOICE OF BREEDING STOCK

One who sees his neighbor's herd frequently and knows many of the animals in it, has a better chance to make correct choices in selecting animals out of that herd than if he selects from a distant herd the first time he sees it or if he buys in an auction sale an animal which may be the only one there from the herd in which it was bred. In the neighboring herd he has a chance to see at several different times or ages any animal he is thinking of buying. Also, he can usually see many of its close relatives. This is helpful in keeping to a minimum the amount he is deceived by environment, by dominance, and by epistasis.

Moreover, he is dealing with a man whose business reputation he knows and one who has a neighborly as well as a business interest in keeping him satisfied with his bargain. If the purchase is unsatisfactory and some adjustment is necessary to satisfy guarantees, there need be little delay and no correspondence or traveling expense. The transportation of the animals to be exchanged is a negligible item. Also, he can more easily satisfy himself about the health of the herd from which he is buying and thereby minimize the risk of introducing disease along with his purchases.

PROMOTING THE CONTINUED USE OF GOOD SIRES

One of the important advantages of community breeding is the ease with which it leads to the exchange of sires thought to be unusually good but which the present owner cannot use longer without close inbreeding. If the general sentiment is in favor of using homebred stock, then a sire proved unusually good by his offspring can be continued in use in neighboring herds without extreme inbreeding. This reaches an extreme form in the dairy bull circles discussed in chapter 32. Another fairly common form is the stallion club for the joint ownership of a good stallion by several farmers; although, if only one stallion is owned, this will not be much help in keeping him in service more than three years. Cow-testing associations are primarily organized to aid in the intelligent culling of cows and in improving feeding practices but can lead to some community breeding.

The exchange and continued use of the best proved sires in each neighborhood, if carried far enough, will ultimately develop linebred families which are distinct from one community to another. When that has happened, comparisons of those families can be made, and weak points of one can be corrected by mild outcrosses to others which are strong in those points. The Homestead family of Holstein-Friesians was a notable example of such community breeding.

Community breeding, if carried far, will tend to make the breeds less uniform than they are today. Probably this would be a real advantage to the utility of the breed, although interchange of breeding stock from great distances would diminish and this would affect some of the commercial aspects of the purebred business.

MUTUAL EDUCATION OF THE BREEDERS

Where many people in one community are breeding the same kind of livestock, there are frequent occasions for them to discuss their problems of breeding, animal health, sales, shows, etc. If this continues long, most of the people in that district soon know much about the lore of that particular breed. Almost without realizing it, they come to possess knowledge and skill ordinarily acquired by isolated breeders only after years of experience. Something of this kind is seen in long-established dairy regions and in the regions of Kentucky and Missouri where saddle horses or Thoroughbreds are raised extensively. Where there is much community interest in the breed, it is not difficult to arrange local shows where the exhibits will be creditable and where lively interest will exist, since nearly all of the animals shown will come from herds which the spectators know personally.

BUSINESS ASPECTS OF COMMUNITY BREEDING

At present commercial necessities must govern the operations of most breeders. Sometimes this operates against community breeding. A prominent Jersey breeder says that many American-bred bulls are as good as the average imported bull but at the same time advises young breeders to use imported bulls to head their herds, since they will find a readier sale for the young bull calves by an imported sire than if they were by an American-bred bull. There is no sound genetic reason for this. It is only that the word "imported" may carry with it a certain glamour which helps break down sales resistance. Things of this kind must be considered by the breeder of purebred livestock. He must find a sale for his young stock; and it is to his advantage, other things being equal, to produce the kind of stock which sells most readily. Interchanging breeding stock from great distances constitutes an economic load on the purebred industry. In many cases there is no commensurate gain. The breeding worth of an animal depends upon its genes; and those are not changed by advertising, although the animal's chance to affect the whole breed by its genes may be much changed by that.

One of the main business advantages of community breeding is that lower selling costs can thus be achieved. If a community contains many herds of one breed of livestock, it may acquire a district reputation in addition to the individual reputation of the breeders residing in it.

This will attract buyers from a distance because they know they can find animals which will suit them without heavy traveling expenses in going from herd to herd. Sometimes a buyer from far away will scarcely bother to stop in districts unless he feels reasonably sure that within driving distance of one loading station he can buy a whole carload of animals which will suit him. This happened frequently in the expansion of the dairy business in the southwestern states during the decade beginning about 1920. Buyers coming from that region with orders for an entire carload of dairy stock would often pass by well-known but isolated herds in Kansas, Missouri, Iowa, and Illinois to go into counties in Wisconsin where they thought they could buy a whole carload in two or three days without traveling far from one shipping station. Community breeding also makes possible the organizing of co-operative consignment sales at a low cost for each animal. Often it is scarcely economical for the ordinary breeder to arrange such a sale since his herd is not large enough that the costs of advertising and holding such a sale could be distributed over enough animals to keep the sales cost per head reasonably low.

Community breeding also makes more effective advertising possible. Several breeders located near the same place may run a single advertisement with the names of all signed to it. There need be no business connection between them except in this advertising. By this means the public is told that each of them has breeding stock for sale and is also informed that there are several different flocks or herds from which to choose, all of them close enough that the buyer may perhaps see them in a single day with a minimum of time and expense.

As a general rule, the formal organization of a community breeding enterprise should be kept as simple as possible. Sometimes it is necessary to have a secretary and a board of directors or executive committee. It is usually possible to avoid the employment of any salaried officer. Such expense might increase the overhead expenses enough to offset the business advantage otherwise inherent in community breeding.

SUMMARY

Most of our breeds were formed originally by more or less definite community breeding. Occasional examples of such community breeding have occurred in America, but this has not yet become the general practice in any nationally important breed.

Because breeders see their neighbors' animals often and know them so much better than they do herds at a distance, fewer mistakes are made in selecting breeding stock from neighboring herds.

Community breeding makes possible the exchange of sires at low cost and thus preserves the services of the best sires without the necessity of close inbreeding.

Community breeding can lead naturally to linebreeding which can be quite effective without the intensity of the inbreeding necessarily becoming high.

Community breeding gives opportunity for exchanging of experiences and discussion of problems, thus helping a breeder acquire knowledge and skill which would take many years if he were operating in a community where he was the only man with his chosen breed.

Community breeding has many business advantages, among the most important of which are lower selling costs, more buyers because of the reputation of the district and the larger number of herds from which to select, co-operative sales, co-operation in advertising, and the effective and economical operation of fairs at which local interest may be keen.

CHAPTER 34

Masculinity and Femininity

In many writings on stock judging and animal breeding, it is urged that sires which are masculine in appearance should be chosen and those which appear somewhat feminine should be avoided. It is likewise stressed that a feminine appearance is desirable in females. One of the reasons occasionally advanced for this is that such individuals will be more prepotent than others. As explained earlier, this is without experimental support. The belief may have arisen incidentally from other and better-founded reasons for desiring full development of the secondary sexual characteristics in breeding animals.

ACTIVITY OF PRIMARY SEX GLANDS

The development of the secondary sexual characteristics is controlled to a large extent by hormones secreted by the primary sex glands (ovaries or testes) in a normally healthy individual. Variations in the expression of secondary sexual characteristics may indicate variations in the activity or state of health of the primary sex glands. Secretion of the sex hormones is not identical with the activity of the sex glands in producing sex cells (ova or spermatozoa). Thus, in ridglings (cryptorchids) the testicle which is retained high in the body cavity rarely produces functional spermatozoa. It seems, however, to secrete the sex hormone in almost if not quite normal amounts. Males possessing a cryptorchid testis but having had the normal testis removed show the secondary sexual characteristics and behavior of normal males, although they are rarely able to beget offspring. Among birds, cases have been reported where individuals which have been functional as females later became apparent males. Nearly all of these birds when dissected show that the ovary (the adult female bird normally has only the left ovary instead of two as mammals have) which had originally been functional when the individual was a normal female had become diseased by tuberculosis, cysts, or some other condition, until it had wasted away and was no longer able to produce the sex hormones. In short, the hen had been