Potential progress in breeding beef cattle depends upon the basic hereditary nature of important traits and the effects of various breeding systems upon their expression. In this presentation we will attempt to summarize research results of recent years, apply them as far as possible to practical situations and discuss application currently being made in industry. It should be recognized that no presentation of this kind can be freed completely from the personal observations and opinions of the reviewer.

Selection in Outbred or Mildly Inbred Populations

This breeding system is essentially one of breeding the "best to the best" without regard to bloodlines. In practice, breeders operate within a breed and may also try to stay within some general bloodline, thus following a mild line breeding program. The breeding program essentially consists of breeding the best available bulls to the available selected cows. It has historically been the most universally used breeding system and present evidence strongly indicates that a good selection system will be basic to breeding programs of the future. It is often termed "mass selection."

Progress which can be made with a mass selection system depends upon (1) the heritability of the traits being considered, (2) their genetic relationships, (3) the number of traits being considered in selection, (4) the intensity of selection which can be practiced, and (5) the reproductive rate.

Put simply, heritability is a statistical estimate of the relative influence of heredity and environment on a trait. In the broad sense, heritability includes all effects of hereditary factors. In usual practice, however, we calculate and think of heritability in the narrow sense. This means that, for the most part, we include the additive gene effects only. Heritability in this sense can be thought of as an index of probable response to selection. It can range from zero to 100 percent for different characters and can vary from herd to herd or from one environment to another for the same character. In spite of the fact that heritability can theoretically reach 100 percent, very few if any quantitative characters in any farm animal have been found to be over about 60 percent. Thus, for practical purposes, we often think of heritabilities of 40 to 60 percent as high, from 20 to 40 percent as medium and below 20 percent as low.
Table 1. Heritability Estimates of Some Economically Important Characters of Beef Cattle.1/

<table>
<thead>
<tr>
<th>Character</th>
<th>Heritability</th>
<th>Character</th>
<th>Heritability</th>
</tr>
</thead>
<tbody>
<tr>
<td>Calving Interval</td>
<td>10</td>
<td>Conformation Score:</td>
<td></td>
</tr>
<tr>
<td>Birth Weight</td>
<td>40</td>
<td>Weaning</td>
<td>25</td>
</tr>
<tr>
<td>Weaning Weight</td>
<td>30</td>
<td>Slaughter</td>
<td>35</td>
</tr>
<tr>
<td>Cow Maternal Ability</td>
<td>40</td>
<td>Carcass Traits:</td>
<td></td>
</tr>
<tr>
<td>Cow Mature Weight</td>
<td>60</td>
<td>Carcass Grade</td>
<td>30</td>
</tr>
<tr>
<td>Feedlot Gain</td>
<td>45</td>
<td>Rib Eye Area</td>
<td>50</td>
</tr>
<tr>
<td>Efficiency of Feedlot Gain</td>
<td>40</td>
<td>Thickness of Fat Cover</td>
<td>30</td>
</tr>
<tr>
<td>Pasture Gain</td>
<td>30</td>
<td>Tenderness of Lean</td>
<td>50</td>
</tr>
<tr>
<td>Final Feedlot Weight</td>
<td>60</td>
<td>Cancer Eye Susceptibility</td>
<td>30</td>
</tr>
</tbody>
</table>

1/ Summarized from many published sources with dependence on summaries by Gregory (1961), and Warwick (1958 and 1960).

Table 2. Estimates of Potential Progress in 10 Years with Natural Service in Large Beef Populations When Selection is For One Trait Only.

<table>
<thead>
<tr>
<th>Trait</th>
<th>Selection Only1/</th>
<th>Selection Plus Progeny Testing 2/</th>
</tr>
</thead>
<tbody>
<tr>
<td>Weaning Weight</td>
<td>43 lb.</td>
<td>47 lb.</td>
</tr>
<tr>
<td>Feedlot Daily Gain</td>
<td>.43 lb.</td>
<td>.48 lb.</td>
</tr>
<tr>
<td>Feed Required per 100 lb. Gain</td>
<td>84 lb.</td>
<td>92 lb.</td>
</tr>
<tr>
<td>Area of Rib Eye</td>
<td>.29 sq. inch</td>
<td>.40 sq. inch</td>
</tr>
<tr>
<td>Tenderness (Shear force required for 1&quot; core)</td>
<td>.88 lb.</td>
<td>1.20 lb.</td>
</tr>
</tbody>
</table>

1/ Five percent of bulls selected solely on basis of own performance and that of half sibs. Bulls used at two and three years, then replaced.

2/ 5.6 percent of bulls selected for progeny testing on basis of own performance, bred as yearlings to 20 cows each for progeny test and the 20 percent having best progeny returned to service at four years and survivors used for five years, then replaced.
Heritability of many beef cattle traits has been studied at experiment stations in the United States and some approximate averages for several characters are shown in Table 1.

The estimates on birth weight, weaning weight, feedlot gain and final weight are based on enough data to give us considerable confidence in their general applicability. Weaning weight is moderately heritable. Feedlot gain and cumulative measures of growth, such as final feedlot weight and mature weight, are rather highly hereditary. Pasture gains are somewhat less hereditary than those in the feedlot.

Estimates on cow maternal ability, i.e. the ability to wean heavy calves, and efficiency of feedlot gain are both based on fewer data. However, these factors appear to be at least medium in heritability. Generally speaking, heritability of measures of growth and maternal qualities appears to be high enough to permit important progress from selection.

Conformation scores appear to be moderate in heritability.

Heritability estimates of carcass characteristics are based upon fewer data. We therefore have less confidence in the applicability of the average figures to beef cattle populations in general. However, all indications are that carcass characteristics are moderate to high in heritability and should respond to selection if means can be devised of putting on selection pressure.

The heritability given for the calving interval is based on only a few estimates but these estimates were generally consistent and also consistent with similar studies in dairy cattle. (Johansson, 1960, and Casida, 1961). The heritability of gross reproductive efficiency is low. Thus we would not expect appreciable progress in improving the genetic capacity for reproduction by the usual selection or culling practices such as culling non-pregnant cows and selecting herd bulls only from cows having had consistent calving records.

Apparently, for most environments at least, automatic selection occurring over long periods of time has nearly exhausted genetic variability in fertility. This could occur because sterile or relatively infertile breeding animals leave none or only a few offspring and thus their germ plasm is effectively culled from the population.

The foregoing statements, which suggest that little or no progress can be expected from selection for fertility, must be taken with some reservations. Knox (1957) found a difference in calf crop of 12.2 percent in favor of large type Hereford cows as compared to smaller, more compact kinds under rigorous range conditions in New Mexico. He hypothesized that the larger cows were better adapted to these conditions and were thus better able to maintain normal reproductive rates. Further evidence that, at least under certain conditions, fertility may be related to type of cow comes from Stonaker (1958), who found that cows of conventional size weaned an 8.4 percent higher calf crop than Comprest type cows under Colorado range conditions. Observations on cow herds in other areas having suboptimum environmental
conditions have led to the suggestion that heritability of fertility may be relatively higher. However, these observations have not yet been buttressed with scientifically acceptable proof. Studies of heritability of various components of reproductive capacity under suboptimum conditions could give different results.

Heritability is an academic concept until we combine it with what we know about variability and the intensity of selection possible and from this material derive estimates of potential improvements in productivity.

Table 2 gives some estimates of potential progress possible over a 10-year period for several traits under natural breeding and two systems of sire selection if selection were entirely for each trait individually. An 80 percent calf crop has been assumed with 60 percent of the heifers put in the herd for breeding. Half of these are culled after two calf crops.

While selection for one item at a time will not normally be a practical procedure, this table has several items of interest:

First, the potential progress in weaning weight and feedlot gaining ability is large. It may not seem large to some of you in view of the reports which keep appearing in the popular press and promotional releases about individual breeders who have increased their weaning weights by 40 lbs. or more in a single year just by getting the right bull. Probably, in most of these cases, the breeder also improved his management and confused the effects of such improvement with bull effects. In some cases, the effect may be truly genetic due to a fortunate sire selection, but for every such case there is probably also an unreported case in which a breeder made little or no progress due to an unlucky sire selection. These things will happen whenever heritability is less than 100 percent. We are interested here, however, in what can be expected on the average in an industry or in a large herd.

Second, the potential progress in reducing feed required per 100 lb. gain is also large but is probably less attainable under practical conditions since it is based on the assumption that every calf would be individually fed so that efficiency could be evaluated. It isn't difficult to get a weaning weight on every calf and to get a post-weaning gain record on every individual, but individually feeding a whole population is another question.

Third, the progress which can be made for carcass traits is disappointingly small because all selection pressure has to be indirect and based on slaughtered animals. (The two traits used are for illustration only; the same principles would apply to others). Relatives of those having the best carcasses are used for breeding. Again, here we've tended to be a bit unrealistic in our assumptions since we've assumed that all animals not needed for breeding were slaughtered and their carcasses evaluated. In the case of the "Selection Only" group, it was assumed that two bulls were selected at random from among the bulls by each sire, the others slaughtered and the bulls used whose half-brothers had the best carcass traits. This is an
inaccurate and not very intense selection procedure. In the "Selection Plus Progeny Testing" group, bulls were initially selected in the same fashion, and all their progeny of both sexes in the progeny test phase were slaughtered. This would give more accurate and intense selection but even then the potential progress would be low due to the fact that the generation interval is necessarily increased.

The examples given may be useful estimates of progress possible in cases where marked deficiencies in one trait make it advisable to select for it alone for a time. Usually, however, concurrent selection will be practiced for several traits. Progress for individual traits will depend upon their heritabilities, the relative emphasis put on each and on the genetic relationships among them. If equal emphasis is put on selection for each trait and if the traits are genetically independent, progress for any one of several traits should be reduced to the progress expected in one trait if it were the sole object of selection divided by the square root of the number of traits being selected for. Thus, if selection were for four independent traits, progress for any one would be reduced by half. However, if all were equally important, total progress or improvement in overall merit would be substantially greater than if all selection were directed to one character. This relationship emphasizes (1) the necessity of avoiding selection for unimportant traits in order to put maximum selection pressure on the important characters, and (2) the desirability of giving attention to all the important traits.

If, in selection, a breeder followed the reasonably practical procedure of giving equal attention to weaning weight, postweaning gaining ability, conformation score and rib eye area, the potential progress over a 10 year period would be 21.22 lb. per day, 1/3 of a grade and .14 sq. inches, respectively. The improvements for weaning weight, gaining ability and conformation score would all be important and could mean much to the industry. Further, there is a relationship between rate of gain and efficiency of gain which makes it probable that the increase in gaining ability would be accompanied by a reduction of 7 to 8 percent in feed required per cwt. gain. Unless the improvement in conformation score were more closely related to carcass value than would appear probable, improvement in carcass value would be disappointingly small.

The problem of selecting for improved carcass quality requires further discussion. Three facts are clearly established:

1. There are large hereditary differences among beef cattle in ability to produce tender, juicy, palatable beef with a minimum of waste fat.

2. Past judging standards have failed to identify those animals with high lean content and indeed apparently have favored those with ability to lay on fat smoothly regardless of lean content or muscling.

3. So far as we know, there are no external indicators of lean tenderness and palatability independent of fatness.
A fourth factor which might be mentioned is that even among highly finished carcasses grading choice or prime there is a small fraction, perhaps 5 percent or less, which are enough lacking in tenderness and palatability to be objectionable to at least some consumers.

If we can't accurately estimate potential carcass quality in the live animal, the only alternative in selecting for it is to breed prospective herd sires to equivalent samples of commercial cows, feed out and slaughter 6 to 10 progeny per sire, evaluate the carcasses, and select the bulls having progeny with superior carcasses for use in seedstock herds. This process is slow, expensive, and the number of bulls which can be progeny tested is limited. It is, however, reasonably accurate and in the absence of better procedures is being used to an extent and will be used more in the future.

What are the alternatives? Improved standards for visual appraisal of live animals are perhaps the most appealing. Studies are under way relating live animal appearance to carcass traits of finished cattle. To date, predictions of lean and fat content have not been highly accurate but some studies show correlations of .3 to .4 between estimates and actual cutouts of closely trimmed rib, loin, round and chuck. These may be high enough to be useful even though much lower than we'd like to have. High cutability seems to be associated with width of shoulder, loin and rump, depth of twist and thickness in arm region. Extreme shortness and depth of body are negatively related. Much remains to be done and visual selection will doubtless always be far from perfect, but I am hopeful we may be able to do a lot with it if our standards are right.

Another possibility is the use of ultra high frequency sound waves to estimate thickness of fat and lean tissues in live animals. Experimental work is promising and these devices are being used to a very limited extent by breeders today. However, much research is still needed on how best to use them. Moreover the machines are expensive and require skilled operators. Other techniques are under investigation.

Since eatability of lean tissue can apparently not be estimated from external appearance, other methods must be used. Taking small biopsy samples of lean from living animals and estimating their potential eating quality is a possibility which comes immediately to mind. Nothing is ready for use as yet but possibilities are being studied. Another real possibility is that the chemist and meat processor will take care of the problem so breeders won't have to worry about it.

In the foregoing material we have given estimates of probable progress through selection. It should be emphasized that these are estimates based on basic facts developed to date. Short-time observations support their probable validity -- actually some of the heritability estimates are based on a one-generation response to selection. However, insufficient time has passed for long-term selection experiments to confirm the validity of estimates.
Genetic correlations are defined as genetic relationships in which genes affecting one character also have effects on others. The effect may be either positive or negative on the second character. If two characters have a positive genetic correlation, selection for one will indirectly result in improvement in the other. Conversely, if negatively related, selection for one will indirectly result in damage to the other.

Accurate estimates of genetic correlations require very large volumes of data. In only a relatively few cases have genetical relationships been adequately studied. However, the following summarizes our present knowledge:

1. There is a positive genetic relationship between growth during different periods of an animal's life. Thus, for example, selection for weaning weight will also result in indirect improvement in postweaning gain. The relationship is not so close, however, that selection in one period is adequate for both.

2. There is a positive genetic relationship between growth rate and efficiency of gain. This relationship is far from perfect, and research workers are not in agreement on whether it is strong enough that selection for rate of gain is adequate for improving efficiency of gain through indirect effects. Presently, few breeders or experiment stations are feeding cattle individually in order to select directly for efficiency. It is possible we will do this in the future.

3. One study strongly suggests there is a negative genetic correlation between maternal qualities of cows and inherent ability to grow to weaning. Selection for weaning weight pertains both to growing ability of the calf and the milking ability of the mother. The study referred to above indicated that selection for weaning weight would result in improvement in both characters—but at a slower rate than would have been possible had these factors not been negatively related. Most importantly this means that if calves are selected for growth under systems such as intense creep feeding or on nurse cows, so that the milking ability of the dam is less important to growth, there may be rather intense indirect selection for poor milking ability. One cannot help but speculate on whether the widespread practice of raising herd sire prospects on nurse cows may be responsible, at least in part, for the poor milking ability of far too many beef cows.

4. Genetic correlations between measures of performance such as weaning weight, postweaning daily gains, and efficiency of gain on the one hand and carcass characteristics such as grade, marbling, proportions of fat and lean, yield of various cuts, tenderness and flavor on the other, are so low that for practical purposes it appears they can be considered independent. This is true at least within the ranges of performance and carcass characteristics usually found in the British breeds of cattle. Thus both performance and carcass traits must be considered in selection. Cattle with
superior performance can have superior carcasses but do not necessarily have them. The reverse is also true.

If it is to prosper, the beef cattle industry must (1) produce a product consumers like, and (2) produce it at a price that consumers are ready and willing to pay. Recognition of this and the foregoing facts has led during the past few years to widespread performance testing of beef cattle. Records have been kept privately by breeders, as well as programs organized under the auspices of State Agricultural Extension Services, breed associations and an organization, Performance Registry International.

In 1961 in Extension programs, weaning records were obtained on the calves of 308,000 cows in 4200 herds, and gain records were obtained on 15,000 young bulls on farms and in central test stations. Also carcass data on progenies of herd sires were collected by 191 breeders. Twenty States now have organizations of breeders working with the Extension Services in organizing and guiding these programs.

For several years a number of the newer beef breed associations have had performance testing programs, and in one association an acceptable growth record is a prerequisite to registration. More recently one of the two largest associations developed a comprehensive plan for evaluating pre- and post-weaning gains and conformation or classification scores. During the past year the two largest associations have announced programs which will aid breeders in getting carcass evaluations of samples of herd bulls' progenies.

It is not our purpose here to discuss specific methods of evaluating performance and carcass desirability in beef cattle. I believe it is appropriate to say, however, that initially performance testing programs in most cases recorded specific information on only a few items. With the passage of time, and with the accumulation of knowledge and the development of procedures and facilities, the techniques used are tending to become more inclusive. This is desirable since, as pointed out earlier, it is no more logical to assume that cattle selected solely for rate of gain will automatically have desirable carcasses than to assume that those selected for conformation standards based on empirical ideas will automatically be economical to produce and have desirable carcasses.

The trend in merchandising breeding stock is unmistakably in the direction of showing objective evidence of inherent ability to economically produce quality beef. This evidence includes:

(1) Heavy weaning weights in relation to cow weight.

(2) Rapid and economical gains from weaning to slaughter.

(3) High carcass content of tender, palatable lean meat with a minimum of waste fat.
All these are of obvious economic importance, and cattle failing in any one just won't fill the bill in the future.

That performance testing can be profitable is indicated by the records of several herds basing their selling program in large part on performance records. Within the past year, a Texas Angus herd sold 123 yearling bulls at auction for an average of $935. An Oklahoma Polled Hereford herd sold 21 1/2 bulls for an average of $1781.

**Genetic-Environmental Interactions**

Genetic-environmental interaction is the term applied to situations in which different strains, types or breeds of animals rank differently in productivity in different environments. For example, if we had two breeds of cattle, A and B, and if A was most productive in Iowa but B was most productive in another section of the country, a genetic-environmental interaction would be evident. The same interpretation would be made if in Iowa, A for instance, was better on a high nutritional regime while B was more productive on a roughage regime.

We do not know the extent or importance of genetic-environmental interactions in beef cattle. The question is of potential importance to the industry in view of (1) the currently almost universal practice of using the same breeds and the same bloodlines almost on a nationwide basis, and (2) the general practice of raising and evaluating seed stock herds under more intensive feeding regimes than those in which their commercial descendants will be raised.

One experiment has been run with hogs and several experiments have been conducted with laboratory animals in which selection was practiced for growth rate (and sometimes other characters too) for several generations in closed lines kept on either high or low planes of nutrition. After several generations, representatives of each strain were switched to the other nutritional level and their performance compared with that of animals whose ancestors had been maintained at that plane of nutrition. In some cases there were no appreciable differences in performance related to the plane on which the animal line was developed. In several cases, lines developed on low planes performed as well or better on the high plane as lines developed on the high plane. However, those developed on the high plane had very poor performance on the low plane - markedly poorer than those developed on it.

In all such experiments with which I am familiar, the lines selected on low planes were as good and often markedly better than those selected on the high plane.

We can't say dogmatically what is the case with beef cattle, but it seems that all logic and the results of experiments with other animals strongly suggest that there would be nothing to lose and possibly much to gain by maintaining seed stock herds in the same type of environments and at relatively the same nutritional levels as will be maintained for their commercial descendants.
Under usual commercial conditions this means a beef cow must be able to exist on pasture or range forage and raise a calf to weaning. After weaning, the bulls should usually be evaluated on a fairly high plane of nutrition since in beef cattle we need ability to perform well in the feedlot as well as adaptation to pasture or range.

**Hybrid Vigor in Beef Production**

Technically, hybrid vigor or heterosis is defined as the amount by which performance of a cross exceeds that of the average of the parental types. From a practical standpoint, the performance of a cross of two breeds must exceed that of the better breed if the cross is to be useful.

Evidence from many species of plants and animals indicates that hybrid vigor is likely to be most pronounced if the strains, lines or breeds crossed are as distantly related as possible and if the types entering the cross are themselves inbred. The latter is probably important principally, at least, because performance of inbred strains is likely to have been reduced and crossing results in regaining the lost performance.

In cattle, the simplest type of cross is a breed cross. Since the three British breeds of beef cattle - the Hereford, Shorthorn and Angus - represent the predominant influence on beef production in the United States, it is fitting that we first examine the evidence for the existence of hybrid vigor in crosses among them.

Table 3 gives in summary form the results of four experiments in which data for several important performance characters are available on both parental breeds and their crosses. Also, results are included of one experiment in which data are available on only one parental breed.

More complete material on fertility and calf survival is available from some experiments than for others, but from the table it is apparent that improvement in both items has occurred with the net result being an increase in percent calf crop ranging from 5.1 to 12.0 percent in the experiments where this information is available. It will be recalled that these traits are low in heritability and unlikely to be improved greatly by selection within breeds or herds. They are apparently significantly affected by hybrid vigor. In one experiment, another reproductive character, age of puberty or first estrus, was significantly younger in crossbred heifers.

In four of the five experiments, growth, both before and after weaning, was more rapid in crossbreds by amounts ranging from 2.4 to 7.8 percent. Thus, in spite of its medium to high heritability, growth seems to exhibit heterosis to a degree. It should be noted that this was not true in the Louisiana experiment. Numbers were small in this study and it may be that only sampling errors are involved. It may be, however, that expression of heterosis depends upon parental stocks.
Table 3. Studies with British Breeds - Advantages of Crossbreds over Straightbreds

<table>
<thead>
<tr>
<th>Study Location</th>
<th>matings</th>
<th>% diagnosed pregnant</th>
<th>% calving</th>
<th>Calf death loss</th>
<th>% calves weaned of cows bred</th>
<th>Weaning weight (both sexes)</th>
<th>Age of puberty (heifers)</th>
<th>Postweaning gain (both sexes)</th>
<th>TDN per 100 lb.gain</th>
<th>Yearling or Slaughter weight</th>
<th>Carcass grade</th>
</tr>
</thead>
<tbody>
<tr>
<td>Fort Robinson, Neb. (Unpub.)</td>
<td>430</td>
<td>4.8%</td>
<td>2.8%</td>
<td>--</td>
<td>5.6%</td>
<td>4.7%</td>
<td>13.5%</td>
<td>2.4%</td>
<td>--</td>
<td>--</td>
<td>--</td>
</tr>
<tr>
<td>Virginia</td>
<td>145</td>
<td>--</td>
<td>9.0%</td>
<td>--</td>
<td>12.0%</td>
<td>3.6%</td>
<td>--</td>
<td>--</td>
<td>0.7%</td>
<td>--</td>
<td>--</td>
</tr>
<tr>
<td>Ohio</td>
<td>195</td>
<td>--</td>
<td>--</td>
<td>3.6%</td>
<td>5.1%</td>
<td>5.1%</td>
<td>--</td>
<td>--</td>
<td>+1.6%</td>
<td>--</td>
<td>--</td>
</tr>
<tr>
<td>Miles City, Louisiana</td>
<td>139</td>
<td>--</td>
<td>--</td>
<td>--</td>
<td>--</td>
<td>--</td>
<td>--</td>
<td>--</td>
<td>--</td>
<td>--</td>
<td>--</td>
</tr>
<tr>
<td>Neb. (Unpub.)</td>
<td>54</td>
<td>--</td>
<td>--</td>
<td>--</td>
<td>--</td>
<td>--</td>
<td>--</td>
<td>--</td>
<td>--</td>
<td>--</td>
<td>--</td>
</tr>
<tr>
<td>Gaines, Gerlaugh, Mont. Knapp</td>
<td>452</td>
<td>9.0%</td>
<td>5.1%</td>
<td>3.6%</td>
<td>5.6%</td>
<td>4.7%</td>
<td>13.5%</td>
<td>2.4%</td>
<td>--</td>
<td>--</td>
<td>--</td>
</tr>
<tr>
<td>Damon et al (1961)</td>
<td>141</td>
<td>--</td>
<td>5.1%</td>
<td>--</td>
<td>12.0%</td>
<td>3.6%</td>
<td>--</td>
<td>--</td>
<td>--</td>
<td>--</td>
<td>--</td>
</tr>
<tr>
<td>et al (1951)</td>
<td>196</td>
<td>--</td>
<td>3.6%</td>
<td>3.6%</td>
<td>5.1%</td>
<td>5.1%</td>
<td>--</td>
<td>--</td>
<td>0.7%</td>
<td>--</td>
<td>--</td>
</tr>
<tr>
<td>et al (1949)</td>
<td>119</td>
<td>--</td>
<td>5.1%</td>
<td>5.1%</td>
<td>5.6%</td>
<td>4.7%</td>
<td>--</td>
<td>--</td>
<td>--</td>
<td>--</td>
<td>--</td>
</tr>
<tr>
<td>et al (1960)</td>
<td>53</td>
<td>--</td>
<td>3.6%</td>
<td>3.6%</td>
<td>--</td>
<td>--</td>
<td>--</td>
<td>--</td>
<td>--</td>
<td>--</td>
<td>--</td>
</tr>
</tbody>
</table>

1/ -- indicates data not available or not reported.

2/ Angus, Hereford, Shorthorn in all possible crosses.

3/ Angus, Hereford and reciprocal crosses. In both studies study, figures of matings are for cows actually calving.

4/ Straightbreds were Herefords, crosses were Shorthorn x Hereford.

5/ Fertility data on four breeding seasons, weaning data on three calf crops, and postweaning data on two calf crops.
Table 4. Studies with Brahman and Charolais-British Crosses - Advantages of Crossbreds Over British Types in Average Daily Gain, Birth to Weaning, Expressed as Percentages 1/

<table>
<thead>
<tr>
<th>Dams</th>
<th>British</th>
<th>Brahman-British Cross</th>
<th>Brahman</th>
</tr>
</thead>
<tbody>
<tr>
<td>British</td>
<td>0</td>
<td>15.0%</td>
<td>11.4%</td>
</tr>
<tr>
<td>Brahman</td>
<td>10.8%</td>
<td>15.6%</td>
<td>1.2%</td>
</tr>
<tr>
<td>Charolais</td>
<td>8.4%</td>
<td>18.8%</td>
<td>22.2%</td>
</tr>
</tbody>
</table>

1/ Data from several Southern stations. Adapted from Kincaid (1962).

Table 5. Some Growth and Carcass Characteristics of British and Brahman Steers, Their Crosses, and Crosses with Charolais 1/

<table>
<thead>
<tr>
<th></th>
<th>:50% British :</th>
<th>:50% British :</th>
<th>50% Brahman :</th>
<th>:50% Brahman :</th>
<th>:Brahman :50% Charolais :50% Charolais</th>
</tr>
</thead>
<tbody>
<tr>
<td>Slaughter age (days)</td>
<td>429</td>
<td>422</td>
<td>405</td>
<td>429</td>
<td>405</td>
</tr>
<tr>
<td>Carcass wt. per day age (lbs.)</td>
<td>1.03</td>
<td>1.15</td>
<td>.98</td>
<td>1.15</td>
<td>1.12</td>
</tr>
<tr>
<td>Dressing percent</td>
<td>57.2</td>
<td>60.1</td>
<td>59.1</td>
<td>58.9</td>
<td>60.2</td>
</tr>
<tr>
<td>Carcass grade 2/</td>
<td>11.1</td>
<td>10.2</td>
<td>8.4</td>
<td>9.3</td>
<td>7.7</td>
</tr>
<tr>
<td>9-10-11 rib cut</td>
<td>30.6</td>
<td>28.5</td>
<td>20.6</td>
<td>26.2</td>
<td>17.5</td>
</tr>
<tr>
<td>% lean</td>
<td>52.1</td>
<td>53.7</td>
<td>58.3</td>
<td>56.0</td>
<td>60.2</td>
</tr>
<tr>
<td>% bone</td>
<td>17.3</td>
<td>17.8</td>
<td>21.1</td>
<td>17.8</td>
<td>20.3</td>
</tr>
<tr>
<td>Warner-Bratzler shear 3/</td>
<td>13.8</td>
<td>15.6</td>
<td>20.2</td>
<td>13.6</td>
<td>15.5</td>
</tr>
</tbody>
</table>

1/ Data from several Southern stations. Adapted from Kincaid (1962).
2/ On scale in which 13 = Choice; 10 = Good; 7 = Standard.
3/ Pounds of force required to shear a 1 inch core of cooked meat. Smaller figures indicate more tender meat.
Carcass grades have shown little or no evidence of being affected by crossing. Likewise, in the two experiments in which it has been reported, efficiency of feed utilization was not appreciably or consistently improved.

It should be emphasized that results shown in Table 3 were all of crosses between straightbred parents. It may well be that crossbred females will express hybrid vigor in fertility and calf raising ability. Critical results on this point will be forthcoming from the Ft. Robinson, Virginia, and Louisiana experiments during the next five years. In other species, notably swine, and in crosses with Brahmans (to be discussed later), this has been the most important heterotic response. The Miles City, Montana, experiment did include the use of crossbred cows and they proved superior to one parental breed in performance. Unfortunately, cows of the other parental breed were not included in the experiment. Preliminary results on maternal performance favored crossbred cows in the Louisiana experiment.

The American Brahman is of the Zebu type and thus much less closely related in origin to the British breeds than they are with each other. Tables 4 and 5 give in summary form some of the more significant results from Southern experiment stations on Brahman-British crosses. It can be seen that in gains from birth to weaning straight Brahmans are only slightly above British types but that crosses made either way result in considerably higher gains, thus demonstrating substantial amounts of hybrid vigor. Crossbred Brahman-British type cows exhibited heterosis in maternal qualities and their use resulted in a further increase in calf gains. Fertility data were not reported in the Southern summary but a Texas report on a herd with rather low average fertility and calf survival showed that Brahman-Hereford crossbred cows were superior both to Brahmans and Herefords and raised a net calf crop 24 and 15 percent better, respectively. In an experiment in Georgia Brahman-Hereford crossbred cows showed better reproductive rates than straight Herefords.

Table 5, on slaughter steers, confirms the existence of heterosis in growth, expressed as carcass weight per day of age, but generally shows the crossbreds to be intermediate in all carcass traits studied except dressing percentage. In this characteristic they exceeded the better parental type by a small margin.

Based on a smaller volume of data, results on crosses of the Charolais with British and Brahman cattle are also given in Tables 4 and 5. These data, and results of limited tests to date at the Ohio Station and at Miles City, Montana, show that Charolais crosses grow rapidly and produce carcasses high in lean and low in fat with lean of acceptable tenderness. By present grade standards, their carcasses grade lower than those of British type cattle. Cow herds of this breed are included in the Ohio and Montana tests and in Texas studies. Thus further experimental evaluation of the breed should be possible within the next few years.

This brief review indicates that heterosis exists in beef cattle breed crosses. If further research and experience with crosses of British breeds confirms the net calf crop increase of five percent or more, coupled with three to five percent faster
growth rate and the production of carcasses of equal quality, it is highly probable that commercial cattlemen in the future will follow crossbreeding systems to a much greater degree than presently. Much additional research needs to be done on the productivity of crossbred cows and on the development of rotational or crisscrossing breeding systems which will permit continuous systematic programs.

The most striking indications of hybrid vigor in beef cattle are from work involving crosses between British types and two breeds, the Brahman and Charolais, of very diverse origins. This suggests the need to intensify research on disease control and quarantine procedures permitting the importation of additional breeds and cattle types. Such animals could be tested as potential beef producers in this country, particularly for use in crosses.

Several experiments on inbreeding beef cattle are under way in which the lines will eventually be evaluated in crosses. Presently, 48 lines closed for five years or more and having inbreeding levels of 10 percent or higher are under study at state and federal experiment stations in the United States. These studies are consistent in showing average decreases in productivity as inbreeding levels increase. The most serious reductions are in fertility and viability, traits which we have already seen are low in heritability and which generally show heterotic responses with crossing. In spite of average reductions in fertility it has proven possible to maintain closed inbred lines at reasonably good levels of performance for long periods of time - in two cases over 25 years.

It is certain, however, that inbreeding depresses performance too much to make it advisable to use inbred lines themselves for commercial production. If they prove useful it will be in crosses.

Due to the long-time nature of experiments with inbred lines, few results on crosses are available as yet. Preliminary results from the Colorado Station and the Miles City, Montana, station show promising performance among crosses of selected inbred lines. It is, however, too early to more than hazard a guess as to whether performance of crossline and topcross animals will be superior to that which could be expected from populations in which an equivalent amount of effort had been expended in mass selection programs.

Artificial Insemination and Estrual Cycle Control

From an industry-wide standpoint, there can be no doubt that genetic improvement could be greatly speeded by artificial insemination programs making widescale use of sires proved outstanding by progeny test. The possible rates of improvement shown in Table 2 could be nearly tripled for carcass traits, doubled for weaning weight, and increased by over 50 percent for gain and efficiency of feed use.
I should emphasize that these potential gains would apply only to large populations. In single herds or small segments of a breed, extensive use of one or a few sires could lead to inbreeding and indirectly to reduced performance.

If artificial insemination is practiced on a wide scale, adequate progeny tests should be made to be sure that the sires used are truly superior in their transmission of performance traits and free of factors for deleterious recessive hereditary defects. If an inferior sire is used the possibility of harm is magnified just as is the possibility of progress through the use of outstanding sires.

Artificial insemination with beef cattle is increasing and has been generally successful in herds where four conditions are satisfied:

1. Semen of good quality is available.
2. Workers skilled in detection of heat are available.
3. Skilled insemination technicians and proper physical equipment are available.
4. Pastures are adequate to maintain the cow herd in a fairly restricted area during the breeding season to facilitate heat detection and minimize distance cows must be moved for insemination.

Where one or more of these conditions has not been met, low conception rates have been encountered.

Artificial insemination with beef herds would be greatly simplified if some method could be developed for bringing entire herds into heat at a single, predictable time with normal conception rates when bred.

Much research is currently being done on this and results at several stations during the past year seem to hold real promise. If and when these are completely successful, artificial insemination in commercial beef herds can be expected to increase greatly.

Summary

Direct selection of beef cattle for traits of economic value should be effective and if widely and systematically practiced could potentially improve several traits important in economical production by from 5 to 10 percent over present averages in a ten year period. Concurrent improvement could be made for carcass traits but at a slower rate since most selection for these traits has to be on a sib and progeny test basis.
Trends in the beef cattle industry appear to be in the direction of intensive selection for characters important in economical production of quality beef. This will involve comprehensive performance testing programs in seed stock herds regardless of the breeding programs used in them and regardless of whether animals from seed stock herds are used commercially in grading, crossbreeding or linecrossing programs. In order to develop cattle with maximum production potential in the areas where their commercial progeny will be raised it seems likely that (1) beef cattle seed stock herds will be raised and evaluated under conditions similar to those in which their commercial descendants will be raised, (2) seed stock herds will be larger, (3) more technically trained people will be involved, and (4) increasing use will be made of technical evaluation methods.

Evidence is accumulating that crossing the British breeds results in considerable hybrid vigor, particularly in fertility and calf survival and to a lesser degree in growth. Carcass traits appear to be little affected by crossing. Preliminary results indicate that crossing inbred lines results in considerable hybrid vigor but the economy of the formation and use of inbred lines as compared to use of stocks developed by selection without intensive inbreeding is not yet established. It appears likely that in the future commercial producers will make increasing use of crossing systems in order to take advantage of hybrid vigor.

There is marked evidence of heterosis in fertility, viability and growth in crosses between British and Brahman type cattle. Carcass characteristics tend to be intermediate with the crosses having higher dressing percentages, more but less tender lean, and less fat than straight British types. In limited experiment station tests crosses of the Charolais with British types have achieved faster growth and carcasses having less fat and more lean of about equal tenderness as compared to British types.
References


Kincaid, C. M., Breed Crosses with Beef Cattle in the South. Southern Cooperative Series Bulletin No. 81, 1962. (published by Texas Agricultural Experiment Station, College Station, Texas).


