Beef Cattle Breeding
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by
Keith E. Gregory, Investigations Leader
Beef Cattle Breeding Research in North Central Region
Animal Husbandry Research Division
Agricultural Research Service

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PREFACE

A systematic record-of-performance program is fundamental to genetic improvement in beef cattle. A clear understanding of breeding principles is essential for developing the most effective breeding practices using such records. This bulletin was prepared to acquaint beef cattle breeders and students of beef cattle breeding with the principles of genetic improvement and record of performance for traits that contribute to efficient production and desirability of product. This information will aid breeders in developing improved breeding practices that will increase the rate of genetic improvement in traits of economic value.

The principles of genetic improvement and record of performance discussed in this publication are based on results of research with beef cattle and other species. Much of the material that pertains specifically to beef cattle breeding has evolved from the three regional research projects on beef cattle breeding. These three regional research projects are cooperative between the State agricultural experiment stations and the Animal Husbandry Research Division, Agricultural Research Service, Department of Agriculture. The three regional projects are the North Central (NC-1), Western (W-1), and Southern (S-10). The sections on "Use of Records," "Major Performance Traits of Beef Cattle," and "Central Testing Stations" have been written so that the reader can obtain some understanding of them with a minimum knowledge of the principles of genetic improvement. However, breeders interested in formulating the most effective breeding plans should also understand the breeding principles discussed in the other sections of this bulletin. Those desiring a more thorough treatment of breeding principles should refer to a textbook on the subject of animal breeding.

For further information and for details regarding specific programs, the reader should consult specialists in beef cattle breeding at his State land-grant college or university.
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Price 25 cents
The major objective of agriculture is the effective use of land. More than half of the land area in the United States is in grass. Beef cattle convert a large part of the production of this enormous land area into a highly palatable and nutritious product. More specifically, they convert the feeds produced on individual farms and ranches into a product in demand by consumers.

The major ways of improving productive efficiency and carcass desirability of beef cattle are through breeding, feeding, disease control, and management.
control, marketing, and management. While this publication is concerned only with breeding, a knowledge of all these areas is fundamental to the economical production of highly desirable beef. These areas may be viewed as a jigsaw puzzle, each of which contributes to completion of the picture of more efficient production of beef with greater consumer desirability.

Only traits that contribute to productive efficiency and carcass desirability are of major economic importance to the beef cattle industry. These economically important traits, frequently referred to as performance traits, are (1) reproductive performance or fertility, (2) mothering or nursing ability, (3) rate of gain, (4) economy of gain, (5) longevity, and (6) carcass merit.

The beef cattle industry in the United States is composed of several segments: (1) the purebred breeder, (2) the commercial producer, (3) the feeder, (4) the packer, and (5) the retailer.
The purebred breeder of beef cattle maintains seedstock herds to provide bulls for the commercial producer. The commercial producer provides feeder stock to the feeder, who in turn provides the packer with finished beef cattle ready for slaughter. The packer slaughters the cattle and provides the retailer with either dressed carcasses or wholesale cuts from these carcasses. The retailer breaks down the dressed carcasses or wholesale cuts into retail cuts, trimmed and packaged suitably for his customers, the consumers.

There is an interdependence among these segments because each affects cost of production or desirability of product, or both. Both desirability and price of product are reflected in changes in consumption. Level of consumption is important to all segments. Once a product is established, consumption or use depends primarily on its price and desirability. Consumption of beef depends primarily on how much it costs the consumers and how well they like it. The profits that accrue to all segments of the beef cattle industry depend on continued improvement in both productive efficiency and carcass desirability.

THE RESPONSIBILITY OF THE PUREBRED BREEDER

The opportunity for genetically improving traits of economic value rests primarily with the purebred breeder or in seedstock herds. Most of the opportunity for selection in beef cattle is among bulls. Level of performance in commercial beef cattle populations is determined primarily by the bulls available to commercial herds from the purebred segment of the industry. For the purebred breeder to discharge his responsibility to the other segments of the beef cattle industry

![Diagram](image_url)

The purebred breeder is concerned with making genetic improvement in ALL traits of economic value in beef cattle production.
with maximum effectiveness, an understanding of the functions of all segments is essential. The pure-bred breeder should possess a working knowledge of genetics (the science of heredity) along with an appreciation of all traits of economic importance to the industry. In addition, he should understand the procedures for measuring or evaluating differences in these traits and be able to develop effective breeding practices for making genetic improvement in all traits that affect efficiency of production and desirability of product.

Expanding human populations will result in an increased demand for beef if present levels of consumption are maintained or expanded. The increase in population and the decreasing availability of land for beef production give impetus to increased productive efficiency. Further reductions in production costs relative to other foods are necessary if beef is to maintain and improve its position among other high-quality protein foods. Additional improvement in desirability of product will aid greatly in maintaining and improving the current acceptance of beef. Improved breeding practices based on systematic records of all traits of economic value should be a major factor in accomplishing these objectives.

**THE BASIS FOR GENETIC IMPROVEMENT**

An understanding of genetics is advantageous to anyone who wants to improve his livestock. This bulletin outlines some of the basic principles of genetics that provide a basis for genetic improvement in beef cattle.

Differences among animals result from the hereditary (genetic) differences transmitted by their parents and the environmental differences in which they are developed. With minor exceptions, each animal receives half its inheritance from its sire and half from its dam. The units of inheritance are known as genes and are carried on threadlike material, present in all cells of the body, called chromosomes. Cattle have 30 pairs of chromosomes. The chromosomes and genes are paired, each gene being at a particular place on a specific chromosome pair. There are thousands of pairs of genes in each animal and one member of each pair comes from each parent. All cells have essentially the same makeup of chromosomes and genes.

Special kinds of tissue in the ovaries of females and the testicles of males produce the reproductive cells. The reproductive cells contain only one member of each chromosome pair, and it is purely a matter of chance which gene from each pair goes to each reproductive cell. In this halving process a sample half of each parent's inheritance goes to each reproductive cell. The genetic potentialities of an individual are determined at fertilization. The pairing of chromosomes restores the full complement when a reproductive cell from the male fertilizes a reproductive cell from the female. This restoration keeps the number of chromosomes constant over countless generations.
Since the half of each of its parents' inheritance that each reproductive cell receives is strictly a matter of chance, some reproductive cells will contain more desirable genes for economically important traits than will others.

The union of reproductive cells that contain a high proportion of desirable genes for economically important traits results in a superior individual, and offers the opportunity for selection. The chance segregation in the production of reproductive cells and recombination upon fertilization is the cause of genetic differences among offspring of the same parents.

The genetic merit of a large number of offspring will average that of their parents. However, some individuals will be genetically superior to the average of their parents and an approximately equal number will be inferior. Those that are superior provide the opportunity for selection and genetic improvement. The basis for genetic improvement is differential reproduction, which is accomplished by permitting some animals to leave a greater number of offspring than others or some to leave offspring while others do not. This is what happens when selection is practiced.

Genes vary greatly in their effects. Some traits are controlled primarily by a single pair of genes, whereas other traits are controlled by many genes. Examples of traits controlled primarily by a single pair of genes are dwarfism and color. Most of the economically important traits—carcass characteristics, growth rate, feed efficiency, and mothering ability—are con-
trolled by many genes. The thousands of genes present make countless combinations possible in any animal. Genes are too small to identify individually, and they manifest their presence by outward effects such as differences in growth rate, feed efficiency, and conformation.

In traits controlled by a single pair of genes, one member of the pair may be dominant. The dominant gene has the capacity for covering up or masking the effect of the other member of the pair. The gene masked is referred to as recessive. For example, the gene for polled masks the gene for horns when both are present. Polled is dominant and horned is recessive. Also, the gene for dwarfism is recessive to the gene for normal appearance. For example, if N represents the gene for normal appearance and n represents the gene for dwarfism, individuals with the "genetic makeup" of NN and Nn are normal in appearance, but Nn individuals carry the gene for dwarfism and transmit this gene to approximately half their offspring. Dwarfs (nn individuals) can result from mating normal-appearing parents if each carries the gene for dwarfism (Nn X Nn). Mating normal-appearing individuals that carry the dwarf gene (Nn X Nn) results in noncarriers (NN), carriers (Nn), and dwarfs (nn) in a 1:2:1 ratio.

Among animals, all differences that are not genetic are classified as environmental. Even though every attempt is made to provide a uniform environment, there are still random environmental differences among animals. For example, identical twins are exactly alike in their genetic makeup but differ in their performance because of random or chance environmental differences. All animals are not at exactly the same place at the same time, grazing the same area, and exposed to the same environmental elements. Some members of a group may contact infectious organisms while others do not. Another example might be injury to the udder of a cow, which would reduce her milk production and result in decreased weaning weight of her calf. There are many random environmental factors that may affect some members of a group and not others, and thus affect the expression of differences in economically important traits.

**GENE FREQUENCY**

The objective of selection for any performance trait is to increase the number or frequency of desirable genes affecting that trait. This is accomplished by selecting animals that are above herd average in genetic merit.

Differential reproduction is the basis for change in gene frequency and genetic improvement. Culling animals that are poor in economically important traits reduces the frequency of undesirable genes in a herd if the culled animals are replaced by animals that are superior in those traits and thus have a higher percentage of desirable genes. Differential reproduction is the basis for continuous improvement in livestock. The increase of desirable genes in one generation is
added to those of the previous generation. For this reason genetic improvement tends to be permanent.

Gene frequency refers to the percentage of the available locations that a particular gene occupies in a herd or population. Since genes are paired in each animal, gene frequency includes both members of each pair and ranges from 0.00 to 1.00. For example, if a herd is free of dwarfism (NN), frequency of the dwarf gene in the herd is 0.00 and frequency of the gene for normal condition is 1.00; it occupies every potential location. Conversely, in a herd of dwarfs (nn), frequency of the dwarf gene is 1.00 and frequency of the gene for normal condition is 0.00. In a herd where all the animals are carriers of the dwarf gene (Nn), the frequency is 0.5 for both genes. Thus, the combined frequencies of both members of a gene pair is 1.00.

KINDS OF GENETIC VARIATION

Genetic variation is caused by either additive or nonadditive gene effects. Many genes are involved in the expression of each performance trait. When these genes produce their effects in a manner comparable to adding block upon block, as in construction of a building, their effects are referred to as additive. The result of selection is to increase the frequency of desirable genes that produce additive effects. The proportion of the total variation (genetic and environmental) due to additive gene effects is called heritability.

In the other basic type of genetic variation — nonadditive — specific combinations of genes produce special effects as a result of being present together. When specific combinations of genes produce a favorable effect, the genetic variation is referred to as “nicking” or heterosis.

Traits vary in the degree to which they are controlled by these two kinds of genetic variation. For traits where most of the genetic variation is additive and it is large compared to the environmental variation, selection based on differences in individual performance will be effective. For traits where most of the genetic variation is nonadditive, selection based on differences in individual performance will be relatively ineffective. For the latter type of trait, the breeding program must be designed to make use of specific crosses that produce favorable gene combinations. This involves crossing lines or groups to obtain favorable combinations of genes for the expression of these traits.

A knowledge of the relative amounts of additive and nonadditive genetic variation that affect each economically important trait is fundamental to the development of an effective breeding program.

FACTORS AFFECTING RATE OF IMPROVEMENT FROM SELECTION

The factors affecting rate of improvement from selection are (1) heritability, (2) selection differential, (3) genetic association among the traits, and (4) generation interval.
Heritability

Heritability is the proportion of the differences between animals—measured or observed—that are transmitted to the offspring. Thus, it is the proportion of the total variation that is due to additive gene effects. The higher the heritability for any trait, the greater the rate of genetic improvement or the more effective selection will be for that trait. For traits of equal economic value, those with high heritability should receive more attention in selection than those with low heritability. Every attempt should be made to subject all animals from which selections are made to as nearly the same environment as possible. This practice will result in a larger proportion of the observed differences among individuals being genetic and will increase the effectiveness of selection. It is important to adjust for known environmental differences before making selections if the environmental factors can be evaluated. Adjustments can be made for differences in age, age of dam, and sex.

The average heritability estimates for some of the economically important traits of beef cattle are presented in table 1. Of the total difference between the selected individuals and the average of the population from which they were selected, the percentage indicated for each trait is actually transmitted to the offspring. For example, if the selected bulls and heifers were 30 pounds above herd average in weaning weight (selection differential), their progeny would be expected to average 9 pounds heavier than if no selection had been practiced for this trait (30% × 30 = 9).

These heritability estimates were obtained under carefully controlled environmental conditions and adjustments were made for known major environmental sources of variation. The heritability of any trait can be expected to vary slightly in different herds, depending on the genetic variability present and the uniformity of environment. However, estimates from different research herds have been reasonably consistent. The heritability estimates in table 1 probably represent average expectations for many herds, provided the general environment is similar for all cattle within the herd. These estimates indicate that selection should be reasonably effective for most performance traits. But since these traits vary both in heritability and economic importance, the rate of improvement in them and the emphasis that

<table>
<thead>
<tr>
<th>Trait</th>
<th>Heritability</th>
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<tbody>
<tr>
<td>Calving interval (fertility)</td>
<td>10</td>
</tr>
<tr>
<td>Birth weight</td>
<td>40</td>
</tr>
<tr>
<td>Weaning weight</td>
<td>30</td>
</tr>
<tr>
<td>Cow maternal ability</td>
<td>40</td>
</tr>
<tr>
<td>Feedlot gain</td>
<td>45</td>
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<tr>
<td>Pasture gain</td>
<td>30</td>
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<tr>
<td>Efficiency of gain</td>
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<tr>
<td>Final feedlot weight</td>
<td>60</td>
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<td>Conformation score:</td>
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<tr>
<td>Weaning</td>
<td>25</td>
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<td>Slaughter</td>
<td>40</td>
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<tr>
<td>Carcass traits:</td>
<td></td>
</tr>
<tr>
<td>Carcass grade</td>
<td>30</td>
</tr>
<tr>
<td>Rib-eye area</td>
<td>70</td>
</tr>
<tr>
<td>Tenderness</td>
<td>60</td>
</tr>
<tr>
<td>Cancer eye susceptibility</td>
<td>30</td>
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they should receive will also vary considerably.

**Selection Differential**

Selection differential is the difference between the selected individuals and the average of all animals from which they were selected. Selection differential is determined by the proportion of progeny needed for replacements, the number of traits considered in selection, and the differences that exist among the animals in a herd. If the average weaning weight of a herd is 450 pounds, and the individuals retained for breeding average 480 pounds, the selection differential is 30 pounds.

The relatively low reproductive rate of beef cattle usually necessitates keeping approximately 40 percent of the females for replacements if the herd is to be maintained and an even higher percentage if the herd is to be expanded. Most of the opportunity for selection is among the bulls, because a smaller percentage of the bulls must be saved for replacement. Increasing the number of traits selected for reduces the opportunity for selection for any one trait. Therefore, it is important to select only for traits of economic value that are heritable.

The low reproductive rate of beef cattle, which necessitates keeping a relatively high percentage (especially females) as replacements, and the large number of traits of economic importance that should be considered in selection place rather severe limitations on selection differentials possible for the various traits. Every effort should be made to get the maximum selection differentials possible for the traits of greatest economic importance and of highest heritability. Traits that have little or no bearing on either efficiency of production or desirability of product should be largely ignored.

**Genetic Association Among Traits**

A genetic correlation among traits is the result of genes favorable for the expression of one trait tending to be either favorable (positive) or unfavorable (negative) for the expression of another trait. If the association is favorable among traits on which selection is based, the rate of improvement in total merit is increased. Conversely, if a genetic antagonism exists among traits, the rate of improvement from selection is reduced.

Available information indicates a favorable association between rate and efficiency of gain and between growth rate in different periods. No major unfavorable genetic association among traits of economic value in beef cattle have been reported, including traits that contribute to both productive efficiency and carcass merit. This is encouraging since simultaneous improvement should be possible in all traits of economic value.

**Generation Interval**

The fourth major factor that influences rate of improvement from selection is the generation interval, that is, the average age of all parents when their progeny are born. Generation interval averages ap-
proximately 4½ to 6 years in most beef cattle herds.

The progress made per generation in any trait is equal to the superiority of the selected individuals above the population average from which they came (selection differential), multiplied by the heritability of the trait. This can be put on a yearly basis by dividing by the average length of generation. For example,

\[
\text{Annual progress for a trait} = \frac{\text{Heritability} \times \text{Selection Differential}}{\text{Generation Interval}}
\]

If heritability of yearling weight is 40 percent, the selected individuals (males and females) are 50 pounds heavier than the average of all animals, and the generation interval is 5 years. The rate of improvement per year in yearling weight would be \( \frac{0.40 \times 50}{5} \), or 4 pounds. It is desirable to keep generation interval relatively short, consistent with obtaining near maximum selection differentials.

**METHODS OF SELECTION**

Selection may be based on (1) pedigree information, (2) individual performance information, (3) progeny test or family performance information, or (4) a combination of all three.

Pedigree information is most useful in selecting among young animals before their own performance or their progeny's performance is known. Pedigree information may also be used in selecting for characters that are measured late in life, such as longevity and resistance to cancer eye, or when selecting for traits expressed only in one sex, such as mothering or nursing ability (selecting bulls out of cows that have produced calves with a high average weaning weight). Pedigree information should be given less attention after information on an individual's own performance or its progeny's performance is available.

Selection on an individual's own performance will result in most rapid improvement when heritabilities are high. An example of such a trait is growth rate. The advantage of selecting on individual performance is that it permits a rapid turnover of generations, and thus shortens the generation interval.

Use of progeny test information results in the most accurate selection if the progeny test is adequate. Progeny tests are most needed in selecting for carcass traits, if good indicators are not available in the live animal; for sex-limited traits such as mothering ability (where individual performance information is not available on bulls); and for traits with low heritabilities. The advantage of using progeny test information over pedigree information and individual performance is accuracy, provided the progeny test is extensive. The disadvantages are the less intense culling possible because of the small proportion of animals that can be adequately progeny tested, the longer generation interval required to obtain progeny test information, and the decreased accuracy as compared to individual performance if
Methods of selection for breeding purposes: (1) On the basis of pedigree, or performance of ancestors; (2) after a preliminary breeding test has been made to permit evaluation of the progeny; and (3) on the basis of individual performance as when, for example, the top 10 percent are selected from a normal distribution.

In summary, pedigree information is useful if selections have to be made early in life before individual performance or progeny test information is available and in selecting for traits expressed late in life such as longevity and resistance to cancer eye, and in selecting for traits expressed only in one sex (mothering ability). Pedigree information is also useful in selecting against inherited defects such as dwarfism.

Individual performance information should be used for traits with high heritability that can be measured in the individual, such as growth rate.

After it becomes available, progeny test information should be used for all traits and is most
needed for traits of low heritability, for certain carcass traits (that cannot be measured in the individual), and for sex-limited traits (traits expressed only in one sex).

A good policy is to make initial selections on the basis of pedigree and individual performance information and let the extent a bull is used in a herd in later years be determined on the basis of progeny test information.

Research indicates that selection based on a combination of individual performance and progeny test information may result in the most rapid rate of genetic improvement for some traits (traits of low heritability or traits that cannot be accurately measured in the individual such as carcass traits). However, for traits of high heritability that can be measured in the individual, selection on the basis of an individual’s own performance is recommended. If progeny test information is used, it is essential that the test be designed so that the results can be properly evaluated. The purpose of a progeny test is to obtain the best estimate of the relative genetic merit of the bulls being tested. Therefore, it is necessary that the cows be assigned to the bulls at random. Selection of cows for a particular bull tends to “stack the cards” either for or against him. A convenient method is to classify the cows by age and line of breeding and to assign the cows to breeding groups at random within line of breeding and age of cow. The sires being progeny tested can then be assigned at random to the different breeding groups.

**TYPES OF SELECTION**

The three types of selection are (1) tandem selection, (2) selection based on independent culling levels, and (3) selection based on an index of net merit.

Tandem selection is selection for one trait at a time. When the desired level of performance is reached in this trait, a second trait is given primary emphasis, etc.

Tandem selection is the least effective of the three types and is not recommended. Its major disadvantage is that by selecting for only one trait at a time, some animals extremely poor in other traits will be retained as replacements.

Independent culling levels require that specific levels of performance be attained in each trait before an animal is kept for replacement. This is the second most effective type of selection. It has this disadvantage: In requiring specific levels of performance in all traits, it does not allow for slightly substandard performance in one trait to be offset by superior performance in another.

Selection based on an index of net merit gives weight to the various traits in proportion to their relative economic importance and their heritability, and takes cognizance of the genetic association (if any) among the various traits. This is the most effective type of selection because it allows slightly substandard performance in one trait to be offset by outstanding performance in another. Also, by giving additional weight to traits of higher heritability or greater economic im-
importance, greater improvement in net merit can be attained.

The use of the index or some modification of it is the preferred type for most herds.

The larger the number of traits selected for, the slower the progress in any one of them; hence the desirability of giving major consideration only to traits of economic value, that have reasonably high heritabilities. The reason why differences in heritability of traits should be considered in selection is that the opportunity for selection should be used on traits that will respond. Obviously, if a trait has extremely low heritability, little genetic improvement in it can be expected. Giving such a trait attention reduces the emphasis that can be put on traits that will give a greater response to selection (higher heritability).

While traits of little or no economic importance or of small heritability should be given little or no attention in selection, all heritable traits of economic value should be considered concurrently, with the attention they receive being determined by their relative economic value and their heritability.

Although increasing the number of traits reduces the selection differential for any one trait, it results in more rapid improvement in total genetic merit or net worth. Average reduction in progress in each trait as a result of considering several traits is approximately \( \frac{1}{\sqrt{n}} \), where \( n \) is the number of traits selected for. For example, if four genetically independent traits are involved in selection, the selection differential for each of them will be approximately half what it would have been if only one trait was involved \( (\frac{1}{\sqrt{4}} = \frac{1}{2}) \). This is based on the assumption that there are no genetic associations (either favorable or unfavorable) among the four traits. It is obvious that considering all heritable, economically important traits simultaneously will result in more rapid improvement in genetic merit involving all traits.

MATING SYSTEMS

There are five fundamental types of mating systems: (1) random mating, (2) inbreeding, (3) outbreeding, (4) assortative mating, and (5) disassortative mating.

Random mating is the mating of individuals without regard to similarity of pedigree or similarity of performance (phenotype).

Inbreeding is the mating of individuals that are more closely related than the average of the breed or population. Linebreeding is a special form of inbreeding.

Outbreeding is the mating of individuals that are less closely related than the average of the breed or population. Crossbreeding is a form of outbreeding.

Assortative mating is the mating of individuals that are more alike in performance traits (phenotype) than the average of the herd or group.

Disassortative mating is the mating of individuals that are less alike in performance traits (phenotype) than the average of the herd or group.
Inbreeding and outbreeding refer to similarity of pedigree or relationship, and assortative and disassortative mating refer to phenotypic resemblance (likeness in performance traits). Phenotype refers to individual performance in all traits that can be measured in an individual.

Linebreeding is a special kind of inbreeding. Linebreeding is the mating of individuals so that the relationship to a particular individual is either maintained or increased. This method automatically results in some inbreeding because related individuals must be mated to accomplish it.

Inbreeding normally has some adverse effects on most performance traits or results in some reduction in general vigor. However, herds of reasonable size, where several sires are used, can be maintained closed to outside breeding for relatively long periods without any appreciable increase in inbreeding or decline in performance associated with inbreeding.

Within a closed herd where the mating is random as far as relationship is concerned, the rate of increase in inbreeding per generation is $1/8m + 1/8f$, where $m$ is the total number of males used in each generation and $f$ is the total number of females in the herd in each generation. Thus, in a 100-cow herd where 4 sires are used per generation with 100 cows in the herd per generation, the increase in inbreeding per generation is $1/8(4) + 1/8(100) = 1/32 + 1/800 = 0.031 + 0.0012 = 0.0322$, or 3.22 percent per generation. If generation interval is 5 years, 15 years on such a program would result in a herd with average inbreeding of 9.66 percent. This is not a very rapid rate of inbreeding. For example, the mating of half brothers and sisters results in offspring that are 12.5-percent inbred. Offspring of sire-daughter, son-dam, and full brother and sister matings are 25-percent inbred. Sire numbers per generation are of paramount importance in affecting rate of inbreeding. The rate of inbreeding can be reduced by deliberately avoiding close matings such as sire-daughter and half brother and sister. Linebreeding—a form of inbreeding—will result in some loss of vigor, but if the animal to which a herd is being linebred is one of truly outstanding merit, the increase in performance as a result of intensifying the genes of an outstanding individual may more than offset any decline in performance due to inbreeding. Rigid selection accompanying linebreeding should be effective in reducing some of the undesirable effects of inbreeding. When inbred or linebred herds are outcrossed, the loss of vigor that accompanies inbreeding is restored.

Linebreeding and inbreeding make the individuals in a herd more alike genetically and thus more uniform in their transmitting ability. A major advantage of linebreeding and inbreeding is that a breeder knows his own herd better than he knows someone else's, and he is likely to do a more effective job of selecting from within his herd.

The effectiveness of linebreeding depends primarily on the genetic
merit of the animal to which the linebreeding is directed.

Many breeders fear the consequences of inbreeding. Inbreeding intensifies what is already present in the herd, including good traits as well as poor. If an undesirable trait is present in the herd, inbreeding will tend to bring it to "light." However, inbreeding is not the cause, as the genes responsible for the undesirable effect were already present. For example, if genes responsible for undesirable traits such as dwarfism are present in a population, inbreeding may increase the number of dwarf calves born, but it is not the cause of dwarfism.

Inbreeding may be used to evaluate the presence of undesirable genes in a herd and, if accompanied by rigid selection, may be effective in reducing the frequency of them.

The disadvantages of linebreeding and inbreeding are that the foundation animals may not be truly superior. A genetic defect in the foundation animals can by chance rise to a high frequency and greatly interfere with the breeding program and materially reduce the value of the herd regardless of its genetic merit for major performance traits. Because it reduces genetic variation, inbreeding results in decreased heritabilities and selection on individual performance is less effective. Since inbreeding makes individuals more alike in their genetic makeup, it increases the effectiveness of family selection.

In summary, linebreeding and inbreeding should be practiced only in herds of outstanding genetic merit. The herds should be large enough so that the rate of inbreeding will be slow enough to provide opportunity for selection before genetic variation is reduced to the point where selection is not effective. All commercial producers and purebred breeders with small herds or herds of only average genetic merit should avoid linebreeding and inbreeding.

Outbreeding is recommended for all commercial producers and for secondary purebred herds. That is, close matings should be avoided. However, owners of secondary purebred herds may profitably secure bulls from linebred herds. If sources of linebred bulls are changed periodically for use in secondary herds, the system is still outbreeding. If it becomes necessary to outcross linebred herds to correct a deficiency, breeders may find it advantageous to outcross to other linebred herds that are particularly outstanding in the trait that needs improvement. After such an outcross it may be desirable to resume a program of linebreeding.

Many breeders practice both assortative and disassortative mating. Assortative mating is practiced by breeders to the extent that they mate their superior cows to their superior bulls. Likewise, they may mate the poorer cows to the unproved or less highly regarded sires. Disassortative mating is practiced when a breeder is attempting to make "corrective matings." That is, he may mate cows that are mediocre or poor in one trait to bulls he considers superior or outstanding in that trait. Assortative mating results in increased variation in a herd, while
disassortative mating tends to reduce the variation in a herd.

**HETEROSIS IN COMMERCIAL PRODUCTION**

Heterosis (hybrid vigor) is the result of nonadditive gene effects and is the difference in performance between crosses and the average of the parental breeds or groups used in the cross. Heterosis results from favorable combinations of genes or groups of genes brought about by specific crosses. Utilization of heterosis necessitates a form of outbreeding. Commercial utilization of heterosis depends on crossing breeds or groups that result in generally favorable genetic combinations.

The phenomenon of heterosis is used extensively in commercial swine and poultry production. However, knowledge of the magnitude of heterosis effects on performance traits of beef cattle is relatively meager. Considerable research is in progress to evaluate effects of heterosis on all performance traits of beef cattle. This research involves the crossing of breeds and the crossing of inbred lines within single breeds. Preliminary results indicate that the effects of heterosis on some traits may be large.

On the basis of experimental results with swine and poultry, it can be expected that the effects of heterosis on beef cattle traits may be inversely proportional to the heritability (additive genetic variation).

**HETEROSIS**

Effect of heterosis on some performance traits may be important. The size of the bar at the right illustrates that, due to heterosis, productivity for some traits is greater in crossbred or cross-line animals than in the average of the parental breeds or strains.
of different traits. Thus, in traits of high heritability one would expect heterosis to be relatively small, whereas in traits of low heritability, heterosis conceivably would be larger. Examples of traits that have low heritability are fertility and livability.

If further research confirms present information on the importance of heterosis on several economically important traits in beef cattle, its effective utilization in practice will still depend on using as breeding stock animals that are superior in their own performance in the traits that have high heritability (additive genetic variation). Not only will use of superior purebred bulls be essential but also additional attention will be required to find specific bulls that combine most favorably with the female herd.

If heterosis proves to have a major effect on several important performance traits of beef cattle, some problems are inherent in its utilization. The overlap of generations among females in the herd is one problem. The percentage of different lines or breeds represented in the females will vary, because only approximately 15 to 20 percent of the female herd is replaced each year. Several different age and breeding groups are present in a herd at a given time. More than one source of bulls must be in service at a time if bulls are used that combine most favorably with the specific females from the different breeding groups. This will require more than one breeding pasture.

While perhaps none of these problems is insurmountable, relatively large herds that can use several breeding pastures are indicated so that females of different crosses can be separated and bred to appropriate sires.

At this time, no general recommendation can be made on the utilization of heterosis in commercial herds. The wisest course of action for commercial producers would appear to be: (1) Keep abreast of research results on the effect of heterosis on important traits, (2) carefully evaluate these results in terms of their own operations, and (3) adopt breeding programs to maximize heterosis in individual herds only when evidence is clear that it will be profitable in terms of the particular operating situation and market outlets.

**GENETIC ENVIRONMENTAL INTERACTIONS**

Genetic environmental interactions refer to the extent to which the same genes contribute to superior performance in different environments. For example, assume two groups or lines of cattle—A and B. If line A is superior in environment 1 but line B is superior in environment 2, a genetic environmental interaction exists. The extent to which cattle superior in one environment maintain that superiority over a wide range of environments is not known. Very little research has been conducted to evaluate the importance of genetic environmental interactions on performance traits of beef cattle. Little
Genetic environmental interactions on performance traits in beef cattle need to be evaluated.

is known about the range in adaptability of different kinds and types of beef cattle to the different climatic conditions and environmental regimes in which they are produced. Research on the adaptability of different types of cattle to different systems of production is now underway.

Beef cattle provide a means of utilizing the feed resources over a wide range of environments (climatic conditions) and in various types of production programs. The environments in which beef cows are carried range from the lush improved pastures of the Corn Belt and southeastern regions to the sparsely vegetated desert ranges of some of the Western States. There is basis to question whether the genetic makeup capable of the maximum response in one environment is the same as the one capable of maximum response in the other environment. For example, is the same cow capable of the most effective utilization of the feed resources in the two environments in terms of calf weaning weight? To obtain maximum use of the feed resources available, the genetic makeup that is best adapted to each situation is the one toward which specific breeding programs should be directed.

An evaluation of genetic environmental interactions and of selection for adaptability to specific climatic conditions and production programs is important to making correct decisions regarding the most effective breeding plans for the maximum utilization of available feed resources.
There are some indications of the importance of adaptation in beef cattle. Evidence includes the seemingly superior performance in some traits of cattle possessing some Brahman breeding under the subtropical conditions of the Gulf coast region. Yet, even in this region, the more the environmental conditions are improved, the less the advantage of the Brahman breeding in these traits. In the more temperate regions, cattle with some Brahman breeding do not seem as well adapted as cattle with British ancestry. More specific questions involving the matter of adaptation relate to specific production programs and practices.

The beef cattle industry is characterized by the movement of breeding stock to conditions greatly different from those in which they and their parents were selected. Such movement also characterizes feeder and replacement cattle for commercial production. The most effective use of the feed resources of this country necessitates movement of many feeder cattle. Perhaps little can be done in this situation even if adaptation is of major importance. However, the great amount of movement of breeding stock, particularly herd bulls, that characterizes the purebred segment of the industry is an undesirable practice if adaptation is of major importance.

Until the importance of genetic environmental interactions is fully evaluated, the wisest course of action for breeders is the selection of breeding stock under environmental conditions that are comparable to those under which their progeny are expected to perform.

**USE OF RECORDS**

Traits of economic value are commonly referred to as performance traits and include all traits that con-

Records of performance provide the basis for selecting genetically superior animals for use in a beef-cattle-breeding program.
tribute to both efficiency of production and desirability of product. Record of performance is the systematic measurement of traits of economic value and the use of these records in selection. The function of record of performance is to help find the genetically superior individuals in all economically important traits so that they may be used for breeding.

The objective of any system of measurements is to make possible the evaluation of differences between animals. The preferred measurements are those that give the most accurate estimate of the breeding value or genetic merit of an animal relative to the others in a herd. Records increase a breeder’s knowledge of differences between animals and thus increase the accuracy of his selections.

Research on beef cattle breeding has demonstrated that appreciable genetic improvement can be made in most traits of economic value by selection on the basis of differences in individual performance. Such research has involved methods of measuring these traits and estimating their heritability, and developing selection procedures for traits that contribute to both productive efficiency and carcass merit.

The systematic measurement of differences among animals in the traits of economic value, the recording of these measurements, and the use of the records in selection will increase the rate of genetic improvement.

Performance records of animals should be adjusted to eliminate known environmental differences between animals so that genetic differences will be a larger part of the total differences measured or observed. Adjustments should be made for differences in age, sex, age of dam, and any other “environmental” variable that can be measured or evaluated. Because any increase in environmental variation tends to obscure genetic differences and decrease the effectiveness of selection, every precaution should be taken to measure economically important traits as accurately as possible. For example, an effort should be made to equalize “fill” in animals before they are weighed, because errors in weighing decrease the accuracy of selection. Fill can be equalized somewhat by removing water and feed for a 12-hour interval before weighing and by recording more than one weight. This applies to both initial and final weights.

Record of performance is useful primarily to provide a basis for comparing cattle handled alike within a herd and not for comparing differences between herds. This is because large environmental differences due to location, management, and nutrition are likely to exist between herds. It is difficult to adjust accurately for these differences. Genetic differences between herds do exist, but large environmental differences make the evaluation of genetic differences extremely difficult.

Average weaning weights of 500 pounds may be realistic in some environments and in some production programs, whereas 350-pound weaning weights may be reasonable un-
der more adverse conditions. Yet, beef cattle may provide the most desirable means of utilizing the land under both conditions. Furthermore, the genetic merit of a herd weaning 350-pound calves may be equal or even superior to that of a herd weaning 500-pound calves. Standards of performance expressed as deviations from individual herd or group averages are advisable for making comparisons within a herd, but comparisons between herds based on minimum standards of performance can be undesirable and misleading.

Minimum standards of performance for the various production and carcass traits have been considered in some record of performance programs. Because of the variation in environmental conditions and production programs, standards involving between-herd comparisons may tend to give recognition to herds carried under superior environmental conditions rather than those that are genetically superior.

Comparing animals within a herd that are subject to different environmental conditions, such as having part of the calves on nurse cows or other variations in feeding and management, is as objectionable as comparing the records of different herds. If variations in treatments exist, comparisons should be restricted to animals treated alike unless appropriate adjustments can be made for treatment effects.

All economically important traits that are heritable should be evaluated for all animals in a herd. An effective record of performance program should be compatible with practical management regimes. Cattle should be evaluated under the approximate environmental conditions in which their progeny are expected to perform.

From the standpoint of genetic improvement for the entire beef cattle industry, record of performance will have greatest impact in purebred or seedstock herds. Commercial producers can use record of performance to cull cows, to select replacement heifers, and to evaluate bulls on their progeny's performance where progeny groups are kept under comparable conditions. Since approximately 40 percent of all heifers must be saved for replacements just to maintain a herd, opportunity for selection among females is limited. Commercial producers can also make effective use of record of performance by selecting bulls on the basis of records from purebred herds that are on a systematic record of performance program. In selecting herd bulls from their own herds as well as from other breeders' herds, purebred breeders should evaluate prospects on the basis of their records as compared to the herd average. Over a period of time, the inherent productivity of any herd depends largely on the genetic merit of the bulls used.

Even as trapnesting in poultry and milk recording in dairy cattle have led to a high percentage of production-bred animals in those species today, record of performance can lead to more economical production of more desirable beef. Systematic programs in a relatively small percentage of the superior
herds can set the pattern for the entire industry.

The goals in record of performance are not greatly different from those that have always been sought by leading breeders. The principal differences lie in a systematic recordkeeping program and the use of these records in making selections. Record of performance up to slaughter requires no new or additional facilities except a scale and forms for keeping records.

The principal features of a good record of performance program are as follows:

1. All animals are given equal opportunity.
2. Systematic, written records are kept of all traits on all animals.
3. Records are adjusted for known sources of variation such as age of dam, age of calf, and sex.
4. Records are used in selecting replacement stock and in culling poor producers.
5. Nutritional program and management practices are practical and compatible with those where progeny of the herd are expected to perform and are uniform for the entire herd.

No effort has been made in this bulletin to include sufficient detail to provide sole guidance for an individual record of performance program. Methods will differ slightly in different areas, and breeders are advised to adopt those generally in use in their areas which best fit their individual needs. For example, breeders in the extreme Southern States may wean calves at 7 or 8 months, while those in Northern States will wean at about 6 months. Some States may use an adjusted weaning weight, others an adjusted gain per day of age.

The relative emphasis put on the different traits may vary in different herds, but the attention that each trait receives should be based primarily on its heritability and economic importance to the entire beef cattle industry. Keeping records does not change what an animal will transmit. Records must be used to locate and use the genetically superior individuals if genetic improvement is to be accomplished.

MAJOR PERFORMANCE TRAITS OF BEEF CATTLE

All traits of economic value should be considered in selecting beef cattle. The major traits influencing productive efficiency of highly desirable beef are (1) reproductive performance or fertility, (2) mothering or nursing ability, (3) rate of gain, (4) economy of gain, (5) longevity, and (6) carcass merit.

Reproductive Performance or Fertility

A high level of reproductive performance or fertility is basic to an efficient beef industry. It is fundamental for making genetic improvement because increased calf crops decrease the percentage that must be saved for replacement and thus increase the selection differential. Efficient cow-calf operations are fundamental to an efficient industry, and no single factor in commercial cow operations has a greater bearing on production costs than does
calf crop. With a higher percentage of our total beef cattle population composed of cows, fertility is an increasingly important trait from the standpoint of total industry efficiency. Both the male and the female should be considered in selecting for fertility, as reduced calf crops can be the result of sterility or partial sterility of either.

Reproductive performance or fertility is a complex trait. So many random or chance environmental factors affect fertility from the time a cow is turned with a bull until her calf is normally weaned that fertility in any given year reveals little of the real genetic differences among cows. Better measures of fertility are needed for both cows and bulls.

Because of the importance of reproductive performance or fertility to efficient production, it must command some attention in a breeding program even though research results indicate that heritability is low and rate of improvement will be slow. There are reported instances where close culling for fertility has improved calf crops. In purebred herds, consideration should be given to culling open cows if they are below average in previous production and all cows open in successive years regardless of production. This assumes that no reproductive disease problems exist. Herd bulls should be selected from cows with good fertility records, be sired by bulls of high fertility, and show high fertility themselves as measured by their ability to settle cows.

In herds where reduced calf crops are a problem, close attention to feeding, disease control, and management practices are definitely indicated. Reproductive diseases markedly influence fertility. Level of feeding—particularly level of energy, vitamin A, and phosphorus—is important. Management of bulls, size of pastures, and distribution of water may be related to whether cows conceive during the normal breeding season. Many breeders and commercial producers can profitably give greater attention to these items in increasing calf crop.

Birth weight

Recording birth weight is optional in a record of performance program. The main advantage of knowing birth weight is in having a more accurate measure of gain from birth to weaning. Direct selection for heavier birth weights would not seem desirable because of the increased likelihood of calving difficulty. Selection for traits that are of major economic importance should favor selection toward the optimum birth weight. Because of a high positive genetic correlation between birth weight and postnatal gain, information on birth weight by sire progeny groups may be useful in deciding which sires to use for their second breeding season since often this is the only progeny information available at the time a decision must be made.

Nursing or Mothering Ability

Weaning weight of calf is used as a measure of mothering ability. The calf's own genetic impulse for growth is confounded with mother-
The ability to wean heavy, vigorous calves is a desirable economic trait in beef cattle and can be improved by selection.

ing ability by this procedure, but this is not a serious handicap since half of the growth impulse of the calf is transmitted by the dam. The ability to wean heavy, vigorous calves is necessary for efficient cow-calf operations. With the trend of marketing cattle at younger ages, weaning age represents a higher proportion of total age at market time and increases the relative importance of weaning weight. Increasing the pounds of calf produced per cow increases efficiency because certain fixed costs such as veterinary, labor, and bull service are on a per head basis. Feed costs for cows seem to be rather closely related to size of cow, but faster gains of calves decrease feed requirements per unit of gain.

It is emphasized that the objective is to increase weaning weight relative to mature cow size. Thus, pounds of calf achieved for each unit of cow weight maintained is a good measure of efficiency of operations from the standpoint of returns per unit of feed.

Selection of bulls and replacement heifers that have heavy wean-
biased and the herd is large enough for reliable estimates to be made. Adjustment factors for smaller herds should be developed from herds with similar management regimes. Records are more accurate where the calving season is relatively restricted so that major differences in age and seasonal influences are avoided. Since weaning weight is used as a measure of mothering ability, it is important that all calves be treated the same for such things as creep feeding, so that the major variable is difference in nursing ability of the cows.

**Growth Rate**

Growth rate is important because of its high association with economy of gain and its relation to fixed costs, such as veterinary, building, and labor, that tend to be on a per head or per unit of time basis. In most instances, differences in growth rate have been measured in time-constant, postweaning feeding tests. Results indicate that differences in growth rate can be appraised rather accurately in this manner. A postweaning period of at least 140 days is required to measure differences in growth rate. This minimum length is based on rather uniform initial weights, condition, ages, and previous treatments. Final weight at 12 to 18 months (standardized for age differences) is probably a better measure of genetic differences in growth rate than any individual component of final weight (that is, birth weight, preweaning gains, and postweaning gains).

Final weight at a standard age of 18 months seems to be a good measure of growth rate, and it fits the management programs of many purebed herds. Bulls can be carried on a relatively low level of concentrate feeding (4 to 5 pounds of concentrates plus full feed of roughage) their first winter and fed at a higher level of concentrate either on grass or in drylot during their yearling summer. By this procedure, bulls are developed at a high-enough level of feeding and over a long-enough period for genetic differences in growth rate to be expressed, and a good appraisal of growth can be made. Bulls handled in this manner are in good sale condition at a desirable age and season. Postweaning gains are measured for approximately 350 days and gains made in this period can be added to 200-day weaning weight, appropriately adjusted for age of dam, to arrive at an adjusted 550-day weight. Final weight and grade at somewhere near normal market age for a high percentage
of slaughter cattle seems to be of most interest on an industrywide basis. The use of postweaning gain alone as a measure of growth could foster poor milking ability because of compensatory gains, in that a poor feed supply in one period tends to be followed by a period of increased rate of gain.

An alternate program for measuring growth rate in bulls is to feed at a higher level and for a shorter period immediately after weaning. Bulls may be put on feed when they are weaned and full-fed for 5 to 6 months a ration of from approximately equal parts of concentrates and roughage to two parts concentrates and one part roughage. In this program an adjusted final weight at 365 days can be used as a measure of differences in growth rate. For example, adjusted 365-day weight may be obtained by adding the gain made in a 165-day postweaning period to 200-day weaning weight, appropriately adjusted for age of dam.

Research results indicate that a reasonably high level of feeding is desirable to appraise differences in growth rate most accurately. If a lower level of feeding is used, the period for measuring differences in growth rate should be longer. However, it is recommended that a relatively low level of feeding (to promote gains of ½ to 1 pound per day) be used for heifers during their first winter. Research results indicate that full feeding a high concentrate ration during the first winter may interfere with reproductive performance and mothering ability. Because a high percentage of heifers must be kept for replacements, there is not much opportunity to select among heifers for differences in growth rate. Hence, from this standpoint, very little can be gained from the heavy feeding of heifers. In selecting heifer replacements for differences in growth rate, it is suggested that long yearling age (approximately 18 months) be used, with adjustments in the same manner suggested for bulls (by adjusting the gain made after weaning to weaning weight, adjusted to a constant age, and appropriately adjusted for age of dam). This assumes that heifers are carried at a relatively low level of feeding during their first winter. If they calve as 2-year-olds, selections may be made at approximately 14 months of age.

The relation of growth rate to differences in composition of gain is of great importance. For example, a 600-pound carcass with 30 percent fat trim will yield approximately the same amount of edible meat as a 470-pound carcass with 10.5 percent fat trim. Such differences in fat trim have been observed in carcasses of the same quality grade. In considering differences in total gain, it seems appropriate to be concerned with differences in composition of gain. Increased rate of gain is of little value if the additional gain is due to fat rather than muscle growth.

**Economy of Gain**

Economy of gain is one of the most important economic traits of beef cattle. Economy of gain is difficult to estimate because it requires
The economy of gain—differences in the amount of feed required to produce a 1,000-pound animal—is one of the most desirable performance traits in beef cattle. Individual feeding and adjustments for differences in weight, since increased weight is associated with higher feed requirements per unit of gain.

Present information indicates that genetic improvement can be made in economy of gain by selecting for it through rate of gain. It is therefore recommended that breeders depend on differences in rate of gain as an indicator of economy of gain rather than incur the added expense of individual feeding. However, if a breeder desires to feed individually and adjust the records for differences in weight in order to measure differences in economy of gain, this is more accurate.

### Longevity

The longer animals remain productive in a herd, the fewer replacements will be needed and thus the costs of growing out replacements to productive age will be reduced. However, the longer an animal remains in a herd, the longer will be the generation interval, which may reduce the rate of genetic improvement from selection. Breeders of purebred cattle or seedstock herds should be concerned with making genetic improvement in longevity so that our commercial beef cattle populations will be productive at older ages. Yet, a fairly rapid turnover of generations in purebred herds is desirable for making a maximum rate of genetic improvement in other traits of economic value.

With the trend toward marketing cattle at younger ages and somewhat lighter weights, a higher percentage of the beef cattle population must be cows in order to produce the same amount of beef. This
higher proportion of cows tends to make longevity of greater economic importance from an industrywide standpoint. Longevity in bulls is important because it decreases the annual cost of bull service.

The major factors affecting longevity are sterility, unsoundness of feet and legs, eye trouble (cancer eye), udder trouble, and unsound mouth. Research has shown susceptibility to cancer eye is heritable, and selection against it should be reasonably effective. However, it is a trait that can be measured only late in life.

Selection for longevity must be confined primarily to indicators such as structural soundness and to pedigree information (selection of close relatives of individuals that have had a long productive life). There is a certain amount of automatic selection for fertility and longevity, because animals that remain in a herd long enough to produce a large number of offspring tend to have a larger number saved for replacements.

**Carcass Merit**

Carcass merit is of fundamental importance to the beef cattle industry. Desirability and price of product are the major factors affecting consumption. In selecting for improved carcass merit, the factors that contribute to carcass desirability and their relative importance must be known. In selecting among breeding animals, the conformation items indicative of desirable carcass traits and ways of measuring or evaluating differences in these traits in live cattle must be available.

Research in many States indicates that the American public desires beef with a high percentage of lean as compared to fat and bone but that the lean must be tender, flavorful, and juicy. The maximum de-
Development of muscling is desired in the regions yielding the more preferred or higher priced cuts—the back, loin, rump, and round.

In grading carcasses, meat quality is determined by marbling, texture, color, and firmness in relation to maturity. Marbling is finely dispersed fat within the muscle; research information indicates that it contributes to juiciness and flavor, but that its relation to tenderness is low. Among carcasses from beef breeds that are similar in other respects, marbling is the major factor that contributes to quality grade. Outside fat is related to marbling when extreme variations in outside fat and marbling are considered. However, the relation between outside fat and marbling at the top end of the carcass grades (Prime, Choice, and Good) is low among cattle that have been fed similarly. The amount of outside fat on a carcass is not a factor in determining quality grade. Large differences in marbling occur in cattle fed and managed in the same manner, and research indicates that part of this variation is due to genetic differences. There are no known reliable indicators in the live animal for predicting marbling. The length of time on feed and the energy content of the ration seem to be the best guides for predicting marbling in live steers.

Thickness of muscling as measured by rib-eye area is one of the more highly heritable characteristics in beef cattle; therefore, selection for muscling should be effective.

Youthfulness is probably one of the best indicators of tenderness; therefore, selecting animals that will reach desirable market weights and grades at young ages should improve tenderness. Research indicates that tenderness is a trait with a fairly high heritability.

As was pointed out in the section on growth rate, difference in composition of carcasses (fat and lean) is a major factor influencing difference in value. Considerable variation in fat trim has been observed in carcasses of the same quality grade. The average choice carcass has somewhere near 20 percent of fat trim upon breakdown to retail cuts with approximately three-eighths to one-half inch of outside fat. Fat trim of choice quality grade carcasses upon breakdown to retail cuts ranges from less than 10 percent to more than 30 percent. Thus, as was pointed out earlier, a 470-pound carcass with 10.5 percent fat trim will yield as much edible meat as a 600-pound carcass with 30 percent fat trim. The value of the fat trim is negligible in today's market.

The two primary factors that determine differences in the real value...
of carcasses are yield of boneless, retail trimmed cuts and quality grade of the carcass. The approach to appraising differences in carcass merit should include these two factors.

The Livestock Division, Agricultural Marketing Service, U.S. Department of Agriculture, has developed a system of grading beef carcasses that describes differences in carcasses for these two factors. This system has been referred to as dual grading, with one grade describing differences in quality of the meat and a separate grade describing differences in estimated yield of boneless, retail trimmed cuts from the round, loin, rib, and chuck. Estimated yield of boneless, retail trimmed cuts from the round, loin, rib, and chuck as a percentage of carcass weight has been referred to as "cutability." These four wholesale cuts represent approximately 80 percent of the value of a carcass and the relation between yield of boneless, retail trimmed cuts from the round, loin, rib, and chuck and from the remainder of the carcass is high. Since differences in yield of boneless, retail trimmed cuts from the round, loin, rib, and chuck, and differences in quality grade are the primary factors that determine differences in carcass value, a carcass merit index combining these two variables is appropriate for ranking carcasses on the basis of value, and for ranking sires on the basis of the carcass value of their offspring.

Studies conducted by the Livestock Division, Agricultural Marketing Service, U.S. Department of Agriculture, have shown that the cuts from the round, loin, rib, and chuck can be predicted rather accurately using fat thickness at the 12th rib, rib-eye area at the 12th rib, percentage of kidney and pelvic fat of the carcass, and carcass weight. Their prediction equation is as follows: Estimated percentage of boneless, retail trimmed cuts from round, loin, rib, and chuck (cutability) = 52.56 - 4.95 (single thickness of fat over rib-eye, [12th rib] inches) - 1.06 (percentage of kidney fat) + 0.682 (area of rib-eye, [12th rib] square inches) - 0.008 (carcass weight, pounds). For example, the computations for a 600-pound carcass with a rib-eye area at 12th rib of 10 square inches, 0.6 inch fat at 12th rib, and 3½ percent of kidney fat would be:

Cutability = 52.56 - 4.95 (0.6) - 1.06 (3.5) + 0.682 (10) - 0.008 (600) = 52.56 - 2.97 - 3.71 + 6.82 - 4.80 = 47.90 percent.

For evaluating animals for carcass merit, it is desirable to combine cutability and quality grade of the carcass into a single index that will describe differences in carcass value. This can be done by combining differences in cutability and differences in quality grade of the carcass into an index of carcass merit.

At 1963 price levels of Prime, Choice, and Good grades, a 2-percent change in cutability has approximately the same effect on value as a change of one full USDA grade in carcass quality. This can be expressed as 2 percent cutability equals 1 quality grade. An index describing this relation would be:

\[ I = \frac{\text{Cutability}}{2} + \frac{\text{Quality Grade}}{1} \]
Since it is desirable to use carcass quality grade to the nearest one-third grade, the correct relation between the values of cutability and grade can be obtained by dividing the quality grade component of the index by 3. Thus, the index would be: \[ I = \frac{\text{Cutability}}{2} + \frac{\text{Quality Grade}}{3}. \]

To simply the index: \[ I = 0.5 \text{ Cutability} + 0.33 \text{ Quality Grade}. \] This index can be further simplified by multiplying by a factor of 2 and the index would then be: \[ I = \text{Cutability} + 0.66 \text{ Quality Grade}. \] For ease of computation it can be rounded to: \[ I = \text{Cutability} + 0.7 \text{ Quality Grade}, \] with quality grade expressed to the nearest one-third of a grade.

Carcass quality grade may be coded to a numerical scale for computing a carcass merit index. Differences among carcasses in the index reflect differences in their real value, if both differences in cutability and carcass grade are weighted according to their relative economic values.

The following numerical values for carcass quality grades are suggested for use in computing indexes:

<table>
<thead>
<tr>
<th>Carcass grade</th>
<th>Numerical value</th>
</tr>
</thead>
<tbody>
<tr>
<td>High Prime</td>
<td>52</td>
</tr>
<tr>
<td>Average Prime</td>
<td>51</td>
</tr>
<tr>
<td>Low Prime</td>
<td>50</td>
</tr>
<tr>
<td>High Choice</td>
<td>49</td>
</tr>
<tr>
<td>Average Choice</td>
<td>48</td>
</tr>
<tr>
<td>Low Choice</td>
<td>47</td>
</tr>
<tr>
<td>High Good</td>
<td>46</td>
</tr>
<tr>
<td>Average Good</td>
<td>45</td>
</tr>
<tr>
<td>Low Good</td>
<td>44</td>
</tr>
<tr>
<td>High Standard</td>
<td>43</td>
</tr>
<tr>
<td>Average Standard</td>
<td>42</td>
</tr>
<tr>
<td>Low Standard</td>
<td>41</td>
</tr>
</tbody>
</table>

Using the index, \( I = \text{Cutability} + 0.7 \text{ Quality Grade}, \) the following example involving 10 carcasses represents its use in practice.

Any descending code scale for quality grade may be used, provided one unit change is equated to one-third of a grade. Thus, 15, 14, and 13 may be used for high, average, and low prime, respectively, with a comparable descending scale for the lower grades.

If ages of the cattle are known, growth rate can be included in the

<table>
<thead>
<tr>
<th>Carcass No.</th>
<th>Cutability</th>
<th>Carcass Quality Grade</th>
<th>Grade × 0.7</th>
<th>Index</th>
<th>Rank in value</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Percent</td>
<td>U.S.D.A. Number Code</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>1</td>
<td>50</td>
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index by adjusting carcass weight to an age-constant basis. Live weight adjusted for differences in age and multiplied by dressing percentage provides an estimate of carcass weight on an age-constant basis. Carcass weight (adjusted for age) multiplied by the carcass merit index yields an index of value of a carcass or an estimate of its worth including growth rate, cutability, and quality of meat.

Obtaining an index of value on the progeny of several different sires should provide a logical basis for ranking them on their most probable genetic worth for several economically important traits. The information is relatively easy to obtain.

While the suggested index may be improved with additional information, the principle is basic; i.e., differences in value are determined by differences in amount of salable meat and differences in quality of the meat.

Conformation Evaluation in Beef Cattle

Performance traits other than carcass merit and structural soundness should be measured directly or through the indicators that have been discussed rather than through conformation.

Conformation is a performance trait to the extent that it contributes to carcass merit and longevity. Basically, the important conformation items are structural soundness, which may contribute to longevity, and beefiness (thickness of natural fleshing or muscling), particularly in the regions of the cuts that contribute most to carcass value (back, loin, rump, and round).

Research is in progress to develop new tools to measure differences in fat and muscling in live beef cattle. Even though research is expected to develop new tools that will result in improved methods of evaluating conformation, it is recommended that breeders use the best current procedures for evaluating differences in the major items of conformation. The term major is emphasized and includes only items of conformation that contribute to carcass merit and longevity—correct skeletal structure or structural soundness, beefiness or thickness of natural fleshing, particularly in the regions of the high-priced cuts, and an optimum finish at a relatively young age.

In evaluating differences in conformation, it is recommended that a score at weaning and one at the time of final weight (12 to 18 months of age) be obtained. The weaning score is probably of less value than final score; therefore, the greatest emphasis should be placed on the final conformation score at 12 to 18 months of age. Since this is somewhere near normal market age for a high percentage of slaughter cattle, it should help guard against producing the "wrong kind"—cattle that are either too early maturing or too late maturing. Size or weight is a measure of growth rate and should not be considered in evaluating conformation. However, it is difficult to score conformation completely independent of growth, since a thrifty, growthy animal that has been doing
well just naturally looks better than one that has not done as well, even though they may be basically the same in the major items of conformation.

A scoring system may be simple or it may include considerable detail, including independent scores of each of the major items of conformation. One with greater detail helps to point out the items of conformation that are good and those that are deficient, such as feet and legs or other structural soundness and natural fleshing. A simple system tends only to group animals of approximately equal desirability from a conformation standpoint without indicating where they are deficient or superior. Each breeder should use a systematic scoring system, choosing for himself whether to use a simple or more complex one.

Research indicates that the differences in outside fat and differences in thickness of muscling can be appraised with limited accuracy by subjective evaluation in live cattle. Quality of the meat (which is determined by marbling, color, texture, and firmness in relation to age) and the amount of edible meat produced per unit of carcass weight are the primary factors that determine real differences in carcass value. The shape of muscling has some effect on desirability when the carcass is broken into retail cuts. Also, thickness of muscling does affect yield of retail trimmed cuts. Among cattle that have been fed alike there is little relation between outside fat and marbling. Marbling is a primary factor in determining carcass quality grade. Therefore, a major objective in assessing differences in the indicators of carcass merit in live breeding cattle is to evaluate differences in the amount of lean relative to fat. Shape of muscling should also be considered. The other major factor to be considered in conformation evaluation is structural soundness, which is indicative of longevity.

Thus, the primary criteria of conformation evaluation in live cattle are (1) structural soundness, which is indicative of longevity, (2) thickness of natural fleshing or muscling, and (3) thickness of outside fat. Differences in thickness of muscling or natural fleshing can be appraised to best advantage in the areas where the least amount of outside fat is normally present. These areas are the outside of the round and the forearm. Differences in outside fat are not greatly associated with differences in marbling and are a major factor affecting yield of retail trimmed cuts. Since outside fat in excess of three-eighths to one-half inch is trimmed off the retail cuts, amounts in excess of this are undesirable. Indicators of outside fat are fullness of brisket and flanks as well as evidences of patchiness around the tail head and over the loin.

Research is in progress to develop techniques for objectively measuring differences in outside fat and muscling in live cattle. Until such techniques are perfected, a subjective score to reflect differences in these traits is recommended. In scoring for differences in fat thickness, an optimum amount of three-eighths to one-half inch is desired in
slaughter steers and heifers. At yearling age, bulls have approximately 0.2 to 0.3 inch less outside fat than steers developed in a comparable manner. Thus, it does not seem that one needs to be greatly concerned by bulls that have less than the amount of outside fat that is optimum for steers, because most of our slaughter steers and heifers have appreciably more than the optimum amount. One of the real opportunities for reducing outside fat in slaughter cattle is to select bulls that have the minimum amount. Indications are that outside fat can be reduced considerably without any appreciable effect on carcass quality grade.

In bulls developed alike it seems reasonable to give independent scores for differences in (1) structural soundness, (2) thickness of natural fleshing or muscling, and (3) outside fat.

CENTRAL TESTING STATIONS

Central testing stations are locations where animals are assembled from many herds to evaluate differences in some performance traits under uniform conditions. Present and potential uses of central testing stations include (1) estimating genetic differences between herds or between sire progenies in gaining ability, grade, ability to fatten, and carcass characteristics; (2) determining the gaining ability, grade, and fattening ability of potential sires as compared to similar animals from other herds; (3) determining gaining ability, grade, and ability to fatten under comparable conditions of bulls being readied for sale to commercial producers; and (4) as an educational tool to acquaint breeders with performance testing.

It is important that the objectives of a central testing station be clearly defined and procedures designed to accomplish the objectives. Since specific objectives and procedures vary with location, only general principles will be discussed here.

In beef cattle, nutritional level at one stage of life usually has carryover effects on performance at later stages. A poor feed supply in one period tends to be followed by a period of increased or "compensatory" gain when rations are increased. Conversely, a higher-than-normal level of feeding will likely be followed by a period of subnormal gains on a normal feeding regime.

Since pretest levels of nutrition and management usually differ from farm to farm or ranch to ranch, performance at a central testing station is influenced by pretest environment. From one standpoint, this is a serious disadvantage of central testing stations, since part of the observed differences at a station will be due to pretest conditions. It will nearly always be impossible to estimate the importance of these effects. However, carryover herd environmental effects will be less important than herd differences due to environment had all animals been fed for a comparable period in the herds in which they were produced. From this standpoint, central test-
ing stations minimize herd environmental effects.

Bull buyers have to decide on (1) which herds to buy bulls from, and (2) which bull or bulls to buy within a herd. If the bulls are raised and fed entirely on the farm or ranch where dropped, the buyer has the nearly impossible task of deciding how much of the apparent superiority or inferiority of bulls in a specific herd is due to feeding and herdsmanship. Having them handled for part of their lives under standard conditions minimizes these effects and makes the task of the buyer easier, whether he is buying commercial bulls or herd sires for a purebred herd.

Similarly, if progeny test groups of steers from different herds are being fed out to determine the transmitting ability of the sires for growth rate, feed efficiency, and carcass characters, sire comparisons are more accurate if all progeny are fed under standard conditions for the final feeding period.

Central tests are of limited usefulness for estimating genetic differences between herds. The larger the herd size, the greater the number needed to adequately sample the herd. The precision of the tests will be greatly improved if five to eight progeny of each of two or more sires from each herd are tested each year. This permits assessment of within-herd differences to compare with between-herd differences. Further, efforts should be made to get a desirable sample of animals from each herd on test or little real information on herd differences will be accumulated. If central testing stations are used to estimate genetic differences between herds, it is recommended that samples of those completing the evaluation be used in top-cross comparisons in commercial herds so that additional traits can be measured and the precision can be increased.

If the purpose is to evaluate individual potential sires, the number tested per herd or per sire is of no importance; but everyone concerned with the test should make a special effort to discourage between-herd comparisons if numbers from each herd are small. Preferably, bulls should be entered in this type of test only if they meet rigid qualifications for preweaning rate of gain and conformation score.

If the purpose is solely to develop bulls and make objective performance information available to prospective buyers, the number of bulls per herd or per sire is immaterial. To be most useful, however, large numbers should be fed at a single location so buyers will have an adequate number from which to choose. Tests of this kind would be most useful as a service to small breeders, and if commercial-type feedlots were used large numbers could be fed.

Influences of pretest environment on test performance can probably never be eliminated, but they can be minimized by the following procedures:

1. Accept animals for test or group them on test only within relatively narrow age ranges, preferably at or shortly after wean-
ing, and from among animals whose pretest treatment has been similar in type of pasture dam was on, whether creep feed was offered, etc. It is important to evaluate differences in growth rate during the period of an animal's life in which growth is most important (before 18 months).

2. Have all animals delivered at a specific time and consider the period immediately after delivery to be an adjustment period. During the adjustment period the animals either can be fed the test ration and the data on gain disregarded or can be fed a low level standard ration. Optimum length of the adjustment period is unknown, and periods ranging from 14 to 90 days have been recommended. Presumably, the longer periods would be more effective.

3. Test for adequate periods, preferably 150 to 180 days if the test is on a fairly high concentrate ration the entire time. Longer tests are desirable if the ration during the test period is high in roughage.

Influences of pretest environment can be minimized in appraisal of results if the final reports include both pretest and test gains. The principal danger of considering test gain only is that cattle on a sub-optimum feeding level prior to test, which did not permit full expression of their inherent ability to grow, are likely to compensate with inflated test gains. Evaluating animals on the basis of both pretest and test gains avoids labeling some unduly high test gain as the animal's real gaining ability.

Preferable methods of doing this are (1) averaging pretest and test gains, or (2) if test starts immediately after weaning, computing a final weight as a standard weaning weight (for example, 200 days) plus test gain. The entire life of the animal must be accounted for; "loaing periods" of unequal or indeterminate length, which would tend to influence subsequent gains, should not be omitted.

The problem of compensatory gain is not limited to central testing stations, since within a herd the inherently fast-gaining calf whose mother was a poor milker is likely to have a low weaning weight with a correspondingly inflated postweaning gain. Comparisons, whether between herds at test stations or within a herd on an individual farm, should give emphasis to both preweaning and postweaning gains.

Central testing stations will be of greatest educational value if all concerned recognize that only a limited number of traits can be evaluated in them and that at best they are merely one phase of a complete performance evaluation program. One of the primary measures of the effectiveness of central testing stations should be the impact they have for increased herd testing for all economically important traits.

Central testing stations can increase problems in the maintenance of herd health. Proper precautions are essential to keep this problem at a minimum.
HEREDITARY DEFECTS OF BEEF CATTLE

A large number of hereditary defects of possible economic importance have been reported in all breeds of beef cattle and also among the dairy breeds. Perhaps the hereditary defect most widely known is "snorter" dwarfism. This defect occurred at troublesome frequencies in some herds in the late 1940's and early 1950's. Discrimination against lines of breeding known to carry this defect has reduced its frequency. This defect, as well as most other hereditary defects, is inherited as a simple recessive. That is, it is due to a single pair of genes that must be present together before the trait is expressed. Such a defect results from the mating of parents, both of which carry the defective gene.

Other types of hereditary dwarfism are due to different genes. "Comprest" dwarfism seems to be due to the action of a gene with incomplete dominance. In other words, the carrier individuals are "comprest," and an extreme type of dwarfism segregates from "comprest" × "comprest" matings. The "comprest" condition in Herefords and the "compact" condition in Shorthorns are probably due to the same gene. "Snorter" dwarfism has been authentically reported in both the Angus and Hereford breeds, and longheaded dwarfism has been reported in the Angus breed. Longheaded dwarfism is also inherited as a simple recessive.

The most practical means of testing a bull for a specific defective recessive gene is to breed him to 16 females that are known to be carriers of the gene. To determine if a bull is a carrier of any genetic defect, the most appropriate test is on his own daughters. On the average, half of the daughters of a bull with a defective gene will be carriers of that gene. After 30 to 35 matings of a bull to his daughters without the occurrence of some genetic defect, one can be reasonably sure that the bull does not carry a genetic defect noticeable in the offspring. The percentage of bulls that are carriers of a hereditary defect inherited as a simple recessive that will not be detected with different numbers and kinds of test matings is presented in table 2.

Although many genetic defects are present in all breeds of beef and dairy cattle and in all classes of farm livestock, defective genes can be coped with if breeders clearly understand them and plan their breeding programs accordingly. Increased frequency of genetic defects in a breed or population can be accounted for either by the gene producing an effect in carriers that causes them to be preferred to non-carriers or where, by chance, a defective gene happens to be present in a line of breeding that is favored.
and is used extensively by the industry. Either condition will increase the frequency of a defective gene in the population or breed.

Defective genes probably cannot be eliminated from our beef cattle populations; they are one of the hazards of breeders. But breeders are responsible for keeping them in check so that they do not become a problem to commercial producers. This can be done most effectively by closely observing operations and by realistically approaching a solution once a problem arises. A realistic approach may require careful screening of herd bulls by progeny testing and the prompt elimination of those proved to be carriers of a defective gene.

If an abnormal calf is born in a herd, the breeder should establish the most probable cause of the abnormality. A limited number of developmental abnormalities may occur that do not have a genetic

### Table 2.—Testing bulls for hereditary defects inherited as simple recessives

<table>
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<tr>
<th>Matings (number)</th>
<th>Percentage of carrier bulls that will not be detected when mated—</th>
<th>To own daughters or to unselected daughters of known carriers of a specific defect</th>
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basis. Only by complete records will the breeder be able to establish the basis for abnormalities. If a breeder decides that an abnormality has a hereditary basis, he should breed away from the source of the trouble, so that the minimum damage will result to his herd and to others. This may be done by outcrossing to a linebred herd after a careful study of the outcross so that the same or an equally undesirable defect will not be introduced. Another means may involve the progeny testing of bulls from his own herd so as to assure that future herd bulls are not carriers of the defective gene. The latter procedure may be indicated if the genetic merit of the herd is particularly high. If only a small percentage of the animals in a herd are possible carriers of the genetic defect, the best course is to eliminate those animals from the herd, provided their genetic merit is not greatly superior to the remainder of the herd.

Since most abnormalities are inherited as simple recessives, both the sire and the dam of abnormal calves are carriers of the defective gene.

While it is unwise to use sons of bulls or cows known to be carriers of defective genes without first progeny testing the sons, discrimination against lines of breeding involving animals several generations removed from a known carrier is unjustified.

Only one-half of the progeny of a bull that is a carrier of a defective gene will be carriers when the bull is mated to cows that are noncarriers. Thus, it seems more reason-
with a minimum of excess fat and the maximum yield of closely trimmed retail cuts from the wholesale cuts of greatest value.

The heritability, genetic association with other traits, and relative economic importance determine the attention each trait should receive in selection. Traits vary in heritability and economic value. The greater the number of traits selected for, the smaller the selection differential will be for any one trait. Traits of low heritability respond less to selection than do traits of high heritability. The opportunity for selection should be used for traits that will result in the maximum genetic progress for the traits of greatest economic value. Obviously, little can be gained and much can be lost by paying too much attention to traits of little economic value and traits of low heritability. While there are genetic differences between herds, evidence indicates that the large differences in feed resources and management programs between herds make it extremely difficult to compare the records of different herds. Thus, comparisons should be among animals in the same herd.

Rate of improvement in most economically important traits of beef cattle will be relatively slow primarily because of the inherently low reproductive rate, the large number of traits of economic value, and the long generation interval. The low reproductive rate, which makes it necessary to keep a high percentage of the offspring, especially females, as replacements, and the large number of traits limit the selection that can be practiced for any one trait. However, most of the economically important traits have reasonably high heritability, fertility being the most notable exception. Even though improvement is slow, it tends to be permanent, accumulates from year to year, and is transmitted to future generations. Over a period of 15 to 20 years, production in a herd or breed that has been subjected to systematic selection for all economically important traits should be noticeably higher than in those where such effort is not made.

A systematic record of performance program with selection based on differences in records is basic to any planned breeding program. The choice of breeding plans and the details relating to them involve many considerations. In seedstock herds, if genetic merit is already high and if the herd is large, is not particularly deficient in some trait of major economic importance, and is relatively free of hereditary defects, a closed herd program of linebreeding may be desirable. One
advantage of proceeding on a closed-herd basis is that the breeder knows the differences in performance of his own cattle better than another breeder's and is in a better position to evaluate differences in their most probable genetic worth.

In large herds where a relatively large number of sires are used in each generation, a closed herd can be maintained for extremely long periods without any appreciable increase in inbreeding if an attempt is made to avoid the mating of close relatives—sire-daughter, full-brother-sister, and half-brother-sister. In herds in which as many as 8 to 10 sires are used per generation, the decrease in performance and the reduction in genetic variation as a result of inbreeding will hardly be noticeable.

If the genetic merit of the herd is already high, it will be difficult to bring in an outcross that is genetically superior to some individuals in the herd. Also, in herds that are relatively free of genetic defects, the chance of increasing this problem with introductions of outside bulls is greater.

If the herd is not large and only a small number of sires are used in each generation, the level of inbreeding will increase more rapidly and performance and genetic variation in the herd will decrease. This decrease in genetic variation decreases the effectiveness of selection.

Whenever a genetic defect is troublesome in a herd, or when performance in some economically important trait is particularly low (some major deficiency exists in a herd), perhaps an outcross is indicated. Although the outcross should be selected primarily to correct the deficiency, the other traits of economic value should also receive major consideration. Outcrossing for any reason, in herds of superior genetic merit, should be done only on a cautious and systematic basis. Minimum sacrifice in other traits is a primary objective when bringing in an outcross to correct some deficiency. In making outcrosses in herds of superior genetic merit, only herds known to be outstanding in the trait of major interest and superior in all traits should be considered. Perhaps this may be another linebred herd. Certainly, records are as fundamental in making selections for outcrossing as they are in making selections from within the herd. After selecting the outcross, a comparison with sires in the herd in a properly conducted progeny test is desirable before extensive use is made of the sires brought into a herd for outcrossing.

In herds that are only average or below in genetic merit, an outcrossing program may logically be the one of choice. However, since most of the opportunity for selection in beef cattle is in the bulls used, records in the herds where bulls are selected should be helpful in locating individuals that have superior genetic merit. Securing outcross sires from linebred herds is desirable. Commercial herds should follow a program of outcrossing.

Pedigree, individual performance, and progeny test information all have a place in a constructive breeding program. Certainly,
young sires should be initially selected on the basis of pedigree and individual performance data. The extent that they are used in a herd will depend on their rank with other sires based on progeny test information. After progeny test information is available, it should be used in making decisions among sires. In using progeny test information, it should be remembered that an increase in generation interval is involved. However, in herds of superior genetic merit, where increased accuracy is of fundamental importance, there is justification for using progeny test information more extensively than in herds only average or below in genetic merit. Perhaps in many superior herds old sires are used more extensively than they should be.

Since generation interval affects rate of improvement from selection, consideration should be given to keeping it relatively short. If a sire is truly superior, he should sire sons that have genetic merit which surpasses his own when he is bred to cows that are comparable in genetic merit to the population that produced him. The problem is one of devising an evaluation program based on use of records that aid in locating such sons. Perhaps one handicap to continued improvement in some herds has been the extensive use of an old sire without sufficient attention to locating sons to replace him. When the old bull passes out of the picture, the herd is left without sires that are superior to him. Continued improvement depends on use of herd bulls that are superior to the ones used in the previous generation.

Before a bull is used extensively in a herd, as would be the case with artificial insemination, it may be desirable to progeny test him for genetic defects on 30 to 35 of his daughters. There are many genetic defects in all livestock, and if a herd is following a linebreeding program, it is desirable to be sure that the bull to which the linebreeding is directed is not a carrier of genetic defects. Bulls that are carriers of defective genes which are likely to be a problem to a herd or breed should be discarded. The purebred segment of the industry is responsible for keeping such defects at a low level so that they will not become a problem to the commercial segment of the industry.

The breeding of cattle of truly superior genetic merit is a great

Herd improvement is accomplished by replacing a sire with his superior sons.
challenges. Many decisions must be made on breeding plans, and selecting herd bulls and replacement females, and on the continued use of herd bulls after some information is obtained on the performance of their progeny. One difficult decision seems to be "dropping" a bull that still has a good market for his progeny even though the breeder may have determined that the bull is not contributing to the accomplishment of his goals, and may be inferior to others in the herd.

The more a breeder knows about the animals in his herd and the more clearly he understands his objectives, the more frequently he should make correct decisions. Success in breeding superior beef cattle, like success in other ventures, depends primarily on the utility of the goals and the accuracy of decisions while working toward the goals. A complete record of performance program provides the basis for making correct decisions.

Goals can be attained only by those who have the objectivity to keep them in perspective and the dedication to remain steadfast in achieving them. They can be accomplished only by a planned breeding program based on the systematic use of records for selection on all traits of economic value.

Progress in beef cattle breeding is relatively slow at best. The life of many purebred herds is not long enough to make appreciable improvement even though the goals of the breeder are sound and his program systematic. Continuity of operation with practical-sized herds and a well-planned breeding program with utility objectives are essential. Sound judgment with the minimum of bias and prejudice is required in evaluating records and in making selections. Breeding beef cattle, like any other business in a healthy economy, is highly competitive. To meet competition successfully, a superior product must be produced. Real merit is necessary to keep a product in demand. This is certainly true with beef cattle.

The contributions to genetic improvement have been made and will continue to be made by those who have chosen goals based on utility. The successful breeders have not been faddists, but have exercised commonsense and good judgment with the long-term outlook in mind. The acceptance and use of new ideas and information is essential to progress in any business.