LINEAR BODY MEASUREMENTS AND OTHER BIRTH OBSERVATIONS ON BEEF CALVES AS PREDICTORS OF PREWEANING GROWTH RATE AND WEANING TYPE SCORE

by

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INTRODUCTION

In the selection of breeding animals it is important to determine their prospective breeding value as early as possible. It is of particular interest for the breeder to know whether any observations taken at birth can be used to predict the future performance of beef calves.

In general, observations on animals can be divided into objective and subjective ones. Objective measurements, as weight or linear body measurements, would depend only on the accuracy with which they were taken, while subjective measurements, such as type or conformation scores, are subject to changes with time and different graders.

The animal breeder faces two problems in grading beef calves. On the one hand, in giving subjective scores for type or conformation, the true value of an individual animal may or may not be expressed, depending upon the grader's ability to judge and the standards used. On the other hand, "objective" linear body measurements disregard that the body form is, geometrically, so complex that it seems impossible to wholly express type by a ratio of simple linear measurements.

The first question then is to what extent birth type in beef calves can be expressed in terms of simple linear body measurements or certain ratios thereof. Or, to put it into biometrical terminology, what is the correlation between birth type and linear body measurements or the regression of birth type on the various measurements? The answer to this question would decide whether any single body measurements or certain ratios of linear measurements may be useful in giving a more objective basis for type grading of beef calves.

The second and more important question is what predictive value birth observations, such as weight, linear body measurements, and type, have for an early evaluation of a calf's prospective performance at weaning or any later growth period. If any of the birth observations were reliable indicators of future performance, then this would permit a preliminary selection before beginning of the next breeding season. This, of course, would considerably speed up genetic progress as compared to selection criteria at weaning or any later growth period.

If, however, birth traits appeared to be uncorrelated with weaning traits and of no predictive value for subsequent performance, then it would seem advisable to disregard all birth observations - except obvious abnormalities, of course - and to put more emphasis on later selection criteria, which might be highly correlated with important economic characteristics.

This study is designed to evaluate a number of linear body measurements taken at birth and to determine their value as

1. an objective expression for birth type;
2. predictors of weaning type score; and
3. predictors of average daily gain from birth to weaning.

Information will also be obtained from this study on the association among birth weight and body measurements, birth weight and preweaning gain, birth type and weaning type, and several other relationships of interest.

REVIEW OF LITERATURE

A. Associations Between Body Measurements and Type:

The literature available on relationships between body measurements and type is confined mainly to mature animals or, at any rate, to postweaning growth periods. Though it seems unjustified to derive any conclusions for a relationship in young calves from observations based on older beef calves, a review of the research with older animals will help to elucidate the present problem.

Hultz (1927) followed the changes in type during a fattening period from the sixth to the twelfth month of age and pointed out that due to unpredictable changes in type it is impossible to select feeder calves on the basis of type with any assurance that they will have a certain type, say "low-set", by the time they are finished.

Brown *et al*. (1956) reported statistically significant relationships between certain body measurements and conformation scores. However, no measurement or combination of measurements had a high predictive value in determining score. Simple correlations varied significantly between the various groups of cattle included in their study, indicating the difficulty in computing specific indices for general application.

It was assumed that the main source of differences in the trend of correlations between stations was due to different grading standards in the mind of the graders. The rather consistent positive correlation between weight and score indicated that larger cattle were favored in type evaluation. Simple correlations between conformation scores and the ratios chest depth to wither height and chest depth to chest height were rather consistently positively related to scores, with correlations ranging from +.15 to +.81 for different groups of animals.

Ternan et al. (1959) evaluated body measurements and conformation scores in yearling steers. They considered heart girth as a more suitable measure of size than body weight for studies of growth and form. A single total score proved to be as useful as a detailed score card evaluation of various components. Repeatability estimates of scores from the beginning and end of the fattening period were reported between .50 and .76. Most of the simple correlations between body measures and conformation score were low or insignificant. Multiple regression equations of score on various measures and ratios accounted for 47 to 59 percent of the variation in score.

Mason (1951) suggested that the live breeding animal may be graded by the ratio of body weight to height at withers or heart girth to height at withers as useful measures of "fleshing".

B. Associations Between Body Measurements and Beef Characters:

During the past forty years there has been considerable endeavor to describe beef type in terms of linear and non-linear body measurements. The usual practice has been to calculate certain ratios involving linear measurements and body weight for use in the prediction of future performance. Most of these studies, again, have been conducted on older beef cattle.

A classical study on the relationship of body shape to rate of gain, to dressing percent, and to value of dressed carcass has been reported by Lush (1932). Correlations among measurements and weight in a group of feeder steers were generally high, reflecting differences in general size. No association was found between gain or dressing percent and a particular body shape, but a small significant correlation existed between gain or dressing percent and general size. The only apparent association between conformation and rate of gain was that large thin steers tended to gain more rapidly. Lush concluded that form and function are not closely enough correlated to permit a reliable prediction of the future performance of an individual animal.

Similar results were reported by Yao et al. (1953), Kidwell (1955), and Woodward et al. (1959). Yao and associates correlated nineteen body measurements with eight meat production characters. They found that width and circumference measurements were positively correlated with slaughter grade, carcass grade, and dressing percentage, and called them fleshing measurements. All height and length measurements were negatively correlated with slaughter grade and called skeletal measurements. Woodward and co-workers concluded from their results that improvement in carcass quality would have to be based on direct selection for the desired characteristics.

Kohli et al. (1951) indicated that body dimensions in fat steers varied independently as indicated by the lack of high correlations between them, except for a fairly high association between height at withers and height at floor of chest.

C. Associations Between Type and Beef Characters:

Type and conformation scores are most important selection criteria in beef cattle. However, their usefulness is restricted to the degree to which they represent economic characteristics, e.g., carcass quality. Selection based on type evaluation at a certain age or growth period of young beef cattle would be of no use or even harmful for economic success and genetic progress, unless the type score represents a reliable information on a calf's economic or breeding value.

Hultz and Wheeler (1927) reported from an experiment with high grade, two-year-old Hereford steers similar in quality, breeding, weight, and condition, that low-set type steers outgained rangy type steers in rapidity and economy of gains.

Koger and Knox (1946) compared the gains of three different types of feeder steers and found that compact cattle consistently gained slower than large cattle. The higher grading of compact cattle caused a negative association between type grade and subsequent gain. No correlation existed between calf grade and carcass grade.

The results reported on correlations between type scores at different times, and between type scores and gain previous or subsequent to type grading are not in full agreement.

Rather high positive correlations among grades in different periods were reported by Carter and Kincaid (1959). Feeder grade at weaning and live slaughter grade had a phenotypic correlation of .36 (genetic .66) for steer calves. The correlation between feeder grade and carcass grade was somewhat lower (phenotypic .16, genotypic .65), while the slaughter and carcass grades were correlated as high as .60 (phenotypic) and .86 (genotypic). In beef heifers, high correlations were found among weaning and yearling feeder grades (phenotypic .56, genotypic .63). Similar high correlations were reported by Koch and Clark (1955b).

Porterfield (1957), working with type scores of Ayrshire heifers and cows, denied the possibility that effective culling for type conformation could be practiced on young animals. Similarly negative results were found by Durham and Knox (1953) for beef cattle.

Rollins and Wagnon (1956) found a within years correlation between weaning weight and weaning grade of .42. Thus, 18 percent of the variation in weaning grades could be explained by variation of weaning weights.

Other research workers regarded the association between type grade and gain as not high enough to be of practical importance for early selection. Knapp and Clark (1951) found a gross correlation of .0001 between score at weaning and gains in the feed lot and concluded that there is little value in selecting feeders for rapid gain if the only selection criterion is weaning type.

Guilbert and Gregory (1952) discussed the usefulness of the present type grading and suggested that conformation now characterizing intermediate type may possibly sometime represent the ideal, similar to the changes in ideal type in swine during the past fifteen years. A "round-height index", computed as a ratio of round measurement x 100 to height at withers, was recommended as an index of earliness of maturity.

Green (1957) reported from a limited number of bull calves a megative correlation between conformation score at the beginning of a feeding trial and the daily gain on feed. This is likely to be the same as the observation of Lush (1932) that large thin steers gained faster on feed lot.

The difficulties involved in grading young cattle were demonstrated by Kidwell et al. (1959), who showed that feeder prices were based largely on feeder grades, but that the feeder grades had little if any association with subsequent rate or economy of gain; nor was carcass value correlated with feeder price, rate or economy of gain.

D. Associations Between Gains During Different Growth Periods:

Prenatal growth was reported to be associated with preweaning growth by workers at the Arizona Station (1937), Nelms and Bogart (1956) and by Thornton (1960). Lasley and Pugh (1956) reported a phenotypic correlation between prenatal and preweaning growth of only .05, but found a high genetic correlation of .72.

Rollins and Guilbert (1954) reported high correlations between the rate of gain from birth to four months of age and the 240-day weaning weight in beef calves, ranging from .62 to .91. It was concluded that gain to four months could be used as a criterion to predict a cow's future production sufficiently well. This is in accord with the results obtained by Green and Buric (1953) in a study on early weaning of beef calves.

Koch and Clark (1955b) reported phenotypic and genetic correlations between birth weight and gain from birth to weaning of .21 and .46, respectively, and pointed out that maternal environment is quite important for birth weight, gain from birth to weaning, and weaning type. Knapp and Black (1941) indicated that differences between sire progeny groups cannot be demonstrated by rate of gain during the period prior to weaning. Little or no relationship was found between preweaning and postweaning gain. Selection of breeding animals on the basis of preweaning growth rate resulted in a definite preference for good milking cows, which obviously were the poorest ones in beef type.

Meyer (1958) divided Black Pied Lowland bull calves into eight groups according to birth weight and compared the growth rates up to 40 weeks. He reported that the difference between the "lowest" and the "highest" group dropped from 41.8 percent at one week of age to only 4.6 percent at 24 weeks. It was concluded that birth weight is not an important selection criterion for economic calf rearing. This is in accord with Bennett (1958), who reported that birth weight in beef calves had no effect on weaning weight.

Kohli et al. (1951) and Dahmen and Bogart (1952), on the other hand, reported significant effects of birth weight on weaning weight and final weight, and on rate and economy of gain in the feed lot, respectively. Dawson et al. (1947) found a low correlation between gestation length and birth weight, but a highly significant negative correlation ($r = -.62$) between birth weight and days from birth to 900 pounds, indicating that birth weight should be considered as a useful selection criterion.

Galgan et al. (1955) compared correlations between preweaning gain and gain while on feeding test of beef calves raised with their dams and those raised without their dams. Correlations among gains for the two growth periods were low (.334) for the calves raised with their dams, but as high as .765 for calves raised without their dams, indicating that it is difficult to select the calves at weaning time that will make good gains in the feed lot.

SOURCE AND DESCRIPTION OF THE DATA

The data used for this study were collected at the Beef Cattle Research Station, Front Royal, Virginia, during the period from 1952 through 1957. During these years birth measurements were taken on all calves of the three main beef breeds, Angus, Hereford, and Shorthorn. Complete records are available on a total of 1425 beef calves, excluding crossbreds and twin calves, which were disregarded for this study because of the small numbers in these groups.

The records on each calf contain the following birth observations: birth weight, height at withers, depth of chest, length of body, length of hips, heart girth, round measure (horizontal measure patella to patella), circumference of cannon bone, and birth type score. The two weaning traits included in this study are weaning type score and average daily gain from birth to weaning.

All linear body measurements are taken in inches and rounded to the nearest tenth of an inch. Birth weights were recorded as rounded to the nearest pound, which was shown to be sufficiently accurate by Lush and Copeland (1928). Average daily gain, computed as the difference between birth and weaning weight divided by the age in days at weaning, was rounded to the nearest hundredth of a pound. Weights and body measurements were taken by one person and as single measurements, in accordance with Touchberry and Lush (1950), who showed that the gain in accuracy by repeating the measurements is only slight and does not justify the additional labor involved.

Midsummer records on the calves are of interest for this study only in so far as at that time one fourth of the bull calves, i.e., a random half out of the lower half of all bull calves, was steered. Because of possible correlations between selection criteria used at midsummer and certain birth observations, it was felt that the steer calves should be treated as a separate group for the birth traits also.

Federal State standards for grades of feeder cattle were used as the basis for type evaluation at both birth and weaning, with a subdivision of the standards into an upper, middle, and lower third of each grade. The complete numerical code used is given below:

17 Fancy plus	11 Good plus
16 Fancy	10 Good
15 Fancy minus	9 Good minus
14 Choice plus	8 Medium plus
13 Choice	7 Medium
12 Choice minus	6 Medium minus

Birth type was graded only once, usually by the same person who recorded the other birth observations. The grade medium minus (6) was not used for birth type in several years, medium (7) being the lowest grade given to any calf born alive. It seemed justified, therefore, to consider the few calves recorded as medium minus (6) as medium (7) for the present analysis and to code them as such.

Weaning type scores were given when the calves were approximately 200 days old. The grading committee consisted of at least five graders, representing the Animal Husbandry Department of the Virginia Agricultural Experiment Station and the Animal and Poultry Research Division of the U. S. Department of Agriculture. The Weaning type scores used in this study are the averages of the scores assigned to a calf by the independent judgment of each grader. These average type scores are recorded as rounded to the nearest tenth of a grade point.

Due to a restricted breeding season at the Front Royal Station, most of the calves are born from January to April. The few calves born in December or later than April were, for this analysis, considered to be born in January and April, respectively.

The management of the herds at the Front Royal Station was the same for all three breeds within a given year, so that environmental differences due to different pasture and herd management should be of no importance in causing breed differences. All calves were maintained on pasture with their dams for the entire suckling period.

A more elaborate discussion of the history and management of the Front Royal beef cattle herds has been given by Lehmann (1959) and will not be repeated here.

METHODS USED IN ANALYSIS OF THE DATA

A. Fixed Environmental Effects:

The first step necessary in analyzing the data was to account for the fixed effects of breed, year, age of dam (at birth of calf), month of birth, and sex of calf. A choice had to be made between three possible ways of removing the fixed effects:

1. It would be possible to consider a fixed effect as randomly distributed and consequently to disregard it for the analysis of the data, as done by Marlowe and Gaines (1958) for the year effects.

2. Calculations could be made within sub-groups, as recommended by Hitchcock *et al*. (1955), and the resulting quantities pooled over all classifications.

3. Estimates of the fixed effects could be obtained by least squares analysis and used as adjustment factors by reversing the sign of the fitted constants. The method presently known as least squares analysis for disproportionate numbers of subclasses was developed by Yates (1934) and has been adapted for the use of high speed computers (V.P.I. Computing Center, IBM 650 Program Library No. 06.2008,1...5).

At the beginning of the analysis it was not known whether important differences existed between the three breeds in the degree or direction of association among the various birth and weaning traits. It was decided, therefore, to make an intra-breed analysis and to remove the effects due to year, age of dam, month of birth, and sex of calf using least squares methods.

Before the matrices for least squares analysis were set up, the age of dam classifications were grouped into five distinct categories, based on the means of all traits and the number of cows within each age group. The purpose of this grouping was to reduce the size of the matrices as far as possible with a minimum loss in accuracy.

Assuming no interactions between year, age of dam, month of birth, and sex of calf, the model could be written:

$$y_{ijkmn} = \mu + a_i + b_j + c_k + d_m + e_{ijkmn}$$

where

y_{ijkmn} is a specified trait of a particular calf within a breed;

μ is the general mean of the specified trait for all calves within a breed;

a_i is the effect of birth year affecting the trait ($i = 1 \ldots 6$);

b_j is the effect of age of dam on the trait ($j = 1 \ldots 5$);

c_k is the effect of birth month on the trait ($k = 1 \ldots 4$);

d_m is the effect of sex of calf on the trait ($m = 1 \ldots 3$); and

e_{ijkmn} is a random effect due to a particular calf, with an expected value of zero.

There was no indication that any of the assumptions for a least squares analysis, i.e., $\Sigma\ e_{ijkmn} = 0$ and homogeneity of the variances, would not hold true for the present analysis.

B. Phenotypic Correlations:

Product moment correlations as outlined by Ostle (1956) were computed to estimate the phenotypic relationship between two variables. The degree of association is determined by the equation

$$r_{xy} = \frac{SP_{xy}}{\sqrt{SS_x \ SS_y}}$$

where

r_{xy} is the phenotypic correlation between two traits;

SP_{xy} is the corrected sum of crossproducts for the two traits;

SS_x is the corrected sum of squares for trait x; and

SS_y is the corrected sum of squares for trait y.

The expected numerical value of product moment correlations is $-1.0 < r_{xy} < +1.0$. The absolute size of the correlation coefficient indicates to what degree the variation of one trait is linearly associated with the variation of another trait. The sign of the correlation coefficient indicates whether with one variable deviating from its mean in one direction the associated variable is likely to deviate from its mean in the same or opposite direction.

Phenotypic correlations were computed among all birth and weaning traits for both unadjusted and adjusted data. Since for this study the approximate magnitude of the correlations across all breeds was of more interest than possible small breed differences, the phenotypic correlations were presented as weighted averages of the three breeds.

In order to justify this kind of presentation, it was necessary to determine whether any significant breed differences existed between the correlations. To test differences in various relationships between the Angus, Hereford, and Shorthorn breeds, i.e., the hypothesis $\rho_A = \rho_H = \rho_S$, the sets of correlations showing the greatest breed differences were chosen. Following the test procedure outlined by Ostle (1956), highly significant differences were found for two sets of correlations, all others being nonsignificant. Since average daily gain was involved in both sets of correlations that showed breed differences, it was decided that all correlations involving average daily gain should be further investigated for breed differences.

The predictive value of all seven body measurements - height at withers, depth of chest, length of body, length of hips, heart girth, round measure, and circumference of cannon bone - in describing birth type and as early indicators of preweaning gain and weaning type was estimated in two different ways:

1. Multiple regression analyses were made involving the seven linear body measurements as independent variables and birth type, weaning type, and preweaning gain as the dependent variables.

2. From the adjusted body measurements seven ratios were computed to be used in analyses of simple linear regression of birth type, weaning type, and preweaning average daily gain, on these ratios.

The squared multiple correlation coefficients (R^2-values) obtained from the multiple regression analysis and the coefficients of determination (r^2-values) obtained from the simple linear regression give a direct measure of the fraction of variation in the dependent trait that may be explained by variation in the independent traits.

Birth weight was not used in the multiple regression analyses as an independent variable with the linear measurements. It was used for an estimate of simple linear regression, serving at the same time as some kind of a "standard" to which the usefulness of the various ratios of measurements could be compared.

RESULTS AND DISCUSSION

A. Grouping of Age of Dam Classifications:

Table 1 presents the means of all birth and weaning observations included in this study: birth weight (B.Wt.), height at withers (Ht.W.), depth of chest (D.C.), length of body (L.B.), length of hips (L.H.), heart girth (H.G.), round measure (R.M.), i.e., the horizontal measure patella to patella, circumference of cannon bone (C.C.), birth type (B.T.), weaning type (W.T.), and average daily gain from birth to weaning (A.D.G.), computed within each age of dam group and across all three breeds. The means were calculated to furnish a logical basis for grouping the age of dam classifications.

With the exception of weaning type, there were little differences between traits of calves out of two and three year old cows. Differences existed for most of the traits between three and four year old dams, and again between the age groups of ten years and over. In general, each trait of the calves approached a maximum as the dam reached maturity and gradually declined after maturity. This trend was more obvious in the two weaning traits than in the birth traits, as may be expected from the fact that maternal environment can affect a calf more during the preweaning period than it can during the prenatal period.

The variability in the older age groups can be explained by the influence of selection, an explanation which may be supported by considering the numbers of cows in each age group. Differences among the

Table 1

Means and Standard Deviations of Birth and Weaning Traits of the Three Breeds, Within Age of Dam

Age of Dam years	Number Calves	B.Wt. lbs.	Ht.W. in.	D.C. in.	L.B. in.	L.H. in.	H.G. in.	R.M. in.	C.C. in.	B.T. Score	W.T. Score	A.D.G. lbs.
2	35	62	24.0	9.5	21.3	7.7	26.6	18.9	4.1	10.4	10.1	1.51
3	283	63	24.1	9.6	21.1	7.7	26.7	18.8	4.1	10.3	11.2	1.54
4	265	67	24.5	9.7	21.6	7.9	27.2	19.1	4.1	10.5	11.3	1.67
5	235	68	24.8	9.8	21.8	8.0	27.3	19.4	4.2	10.5	11.4	1.72
6	194	70	24.9	9.8	22.0	8.0	27.4	19.5	4.2	10.6	11.4	1.74
7	131	69	24.9	9.8	22.0	8.1	27.4	19.4	4.2	10.6	11.2	1.72
8	93	68	25.0	9.8	21.7	8.1	27.5	19.4	4.2	10.1	11.2	1.70
9	53	70	25.5	9.9	22.1	8.3	27.7	19.6	4.2	10.5	10.8	1.63
10	34	70	24.9	10.0	22.3	8.0	27.8	19.4	4.2	10.7	10.8	1.62
11	33	66	24.1	9.7	21.8	7.7	27.4	19.2	4.2	10.3	10.7	1.63
12	30	64	24.4	9.9	21.7	7.8	26.9	19.2	4.2	10.4	10.4	1.48
13	19	66	24.3	9.8	21.4	7.8	27.0	19.5	4.2	10.2	10.2	1.60
14	12	60	23.6	9.5	20.6	7.6	26.2	18.7	4.1	9.9	10.2	1.49
15	6	60	23.8	9.1	20.5	7.3	25.9	17.6	4.0	8.2	10.8	1.62
16	2	66	25.0	10.0	22.0	7.8	26.7	19.2	4.2	10.5	9.5	1.54
Stand. Dev., Pooled Within Age of Dam		9.4	1.4	0.7	1.5	0.6	1.4	1.4	0.3	1.4	1.5	0.29

ages from four to ten years are relatively small, but due to the large number of cows in those age groups, it was felt that not more than two years should be combined into one group. It was decided to combine the age of dam classifications into five groups: two and three year olds, four and five year olds, six and seven year olds, eight and nine year olds, and ten through sixteen year olds.

The general trend of the effect of age of dam on calf birth and weaning traits as shown in table 1, is well in accord with other work (Dawson et al.,1947; Venge, 1948; Burris and Blunn, 1952; Galgan et al., 1955; Marlowe and Gaines, 1958; and Thornton, 1960).

The only difference which seems to exist between the present and other reports is that the major break between young and mature cows was found in this study between the three and four year old cows, while in most of the other studies reviewed this break appeared between the two and three year old cows. Apparently the decisive factor is not age expressed in years but rather what could be called physiological age, i.e., age as determined by sequence of lactation and factors of herd management. From the numbers of cows in the two and three year old groups (table 1) it can be seen that most of the cows had their first calf at an age of three years. It is likely that the heifers were selected for early breeding on the basis of their relative maturity, so that the physiological age of cows calving for the first time at three years may not have been too different from those cows calving at two years. Obviously, a higher performance of the few cows being in their second lactation at three years of age would not greatly affect the means in that age group.

B. Estimates of Fixed Effects from Least Squares Analysis:

Solution of the normal equations yielded the estimates shown in tables 2, 3, and 4. Only those constants were used as adjustment factors that showed statistical significance at least at the 5 percent probability level. This seemed justified because the use of constants that hardly exceed their standard deviations in size, would not appreciably reduce the variance of a trait. No additional decimals were introduced in adjusting the data. Therefore, a few factors that showed statistical significance but were very small in size, could not be used for adjusting the data.

Generally, it appears that the effects due to year, age of dam, month of birth, and sex of calf vary considerably among the various traits within a breed and between breeds for the same trait as well. The effect of year was, on the average of all traits, more important in the Angus and Hereford breeds than in the Shorthorn breed. Age of dam had an apparent effect on the lowest age group, but was of little importance for all other groups. The effect of birth month was generally low due to a restricted breeding season, but April calves, on the average, outweighed earlier calves and consequently were larger in most of the body measurements. In weaning type, April calves scored significantly lower than earlier calves. Preweaning growth rate was significantly lower for January calves of the Hereford and Shorthorn breeds, but not of the Angus breed.

Sex of calf had a highly significant effect in that the bull calves outweighed and outgained heifer calves consistently. Calves

Table 2

Estimates of Constants from Least Squares Analysis, Angus Calves

Effect	Number Calves	Birth Weight	Height at Withers	Depth of Chest	Length of Body	Length of Hips
Deviation from Base due to:		b s_b	b s_b	b s_b	b s_b	b s_b
Year of Birth						
1952	42	2.9 ± 1.5*	-.4 ± .2	.5 ± .1**	1.3 ± .2**	.0 ± .1
1953	68	0.5 ± 1.3	-.7 ± .2**	.2 ± .1*	.4 ± .2*	-.1 ± .1
1954	64	4.0 ± 1.3**	-.1 ± .2	.3 ± .1**	.5 ± .2*	.1 ± .1
1955[1]	92					
1956	101	5.6 ± 1.1**	.0 ± .2	.2 ± .1**	.0 ± .2	.5 ± .1**
1957	106	6.5 ± 1.1**	.8 ± .2**	-.4 ± .1**	.4 ± .1**	.4 ± .1**
Age of Dam						
2-3 years	104	-4.5 ± 1.0**	-.4 ± .2**	-.2 ± .1*	-.5 ± .2**	-.2 ± .1**
4-5 years[1]	176					
6-7 years	117	1.2 ± 0.9	.1 ± .1	.1 ± .1	.5 ± .2**	.1 ± .1
8-9 years	50	0.9 ± 1.3	.3 ± .2	.3 ± .1**	.4 ± .2	.2 ± .1
10-14 yrs.	26	-0.6 ± 1.6	.1 ± .3	-.0 ± .1	.1 ± .3	.1 ± .1
Month of Birth						
January	101	0.9 ± 0.9	-.2 ± .1	-.0 ± .1	-.3 ± .2	-.2 ± .1**
February[1]	240					
March	89	0.9 ± 1.0	.3 ± .2	-.0 ± .1	.2 ± .2	.2 ± .1**
April	43	5.8 ± 1.3**	.5 ± .2*	.1 ± .1	.[illegible] ± .2	.3 ± .1**
Sex of Calf						
Bulls	179	5.5 ± 0.8**	.3 ± .1**	.2 ± .1**	.2 ± .1	.2 ± .1**
Heifers[1]	247					
Steers	47	3.4 ± 1.2**	.2 ± .2	.1 ± .1	.1 ± .2	.2 ± .1*

Table 2 (continued)

Effect	Heart Girth	Round Measure	Circ. of Cannon	Birth Type	Weaning Type	Weaning A.D.G.
Deviation from Base due to:	$b \pm s_b$	$b \pm s_b$	$b \pm s_b$	$b \pm s_b$	$b \pm s_b$	$b \pm s_b$
Year of Birth						
1952	.9 ± .2**	.5 ± .2*	.10 ± .05*	.8 ± .3**	-.3 ± .3	-.02 ± .04
1953	.4 ± .2	-.1 ± .2	.07 ± .04	-.0 ± .2	-.8 ± .2**	-.02 ± .03
1954	.1 ± .2	1.4 ± .2**	.03 ± .04	1.0 ± .2**	-.1 ± .2	.04 ± .03
1955[1]						
1956	1.2 ± .2**	.8 ± .2**	.13 ± .04**	.1 ± .2	-.2 ± .2	.11 ± .03**
1957	.2 ± .2	.6 ± .2**	-.05 ± .04	.5 ± .2*	-.8 ± .2**	-.04 ± .03
Age of Dam						
2-3 years	-.6 ± .2**	-.4 ± .2*	-.05 ± .03	-.4 ± .2	-.2 ± .2	-.12 ± .03**
4-5 years[1]						
6-7 years	.1 ± .1	.1 ± .1	.01 ± .03	-.1 ± .2	-.0 ± .2	.00 ± .02
8-9 years	.3 ± .2	.1 ± .2	.05 ± .04	-.3 ± .2	-.4 ± .2	.03 ± .03
10-14 yrs.	.2 ± .3	-.2 ± .3	-.02 ± .05	-.8 ± .3*	-.9 ± .3**	-.07 ± .04
Month of Birth						
January	.1 ± .1	-.3 ± .1	.07 ± .03*	.2 ± .2	-.0 ± .2	-.04 ± .02
February[1]						
March	-.1 ± .2	.4 ± .1*	.02 ± .03	.3 ± .2	-.0 ± .2	.03 ± .03
April	.5 ± .2*	.6 ± .2**	.04 ± .04	.4 ± .3	-.8 ± .3	-.03 ± .04
Sex of Calf						
Bulls	.6 ± .1**	.6 ± .1**	.25 ± .02**	.5 ± .1**	-.5 ± .1**	.26 ± .02**
Heifers[1]						
Steers	.3 ± .2	.3 ± .2	.17 ± .04**	.3 ± .2	-1.3 ± .2**	.03 ± .03

[1] Base Effect
* significant at $P < .05$
** significant at $P < .01$

Table 3

Estimates of Constants from Least Squares Analysis, Hereford Calves

Effect	Number Calves	Birth Weight	Height at Withers	Depth of Chest	Length of Body	Length of Hips
Deviation from Base due to:		b s_b	b s_b	b s_b	b s_b	b s_b
Year of Birth						
1952	70	4.2 ± 1.4**	-.3 ± .2	.3 ± .1**	1.3 ± .2**	.1 ± .1
1953	90	4.1 ± 1.2**	-.1 ± .2	.3 ± .1**	.9 ± .2**	-.0 ± .1
1954	94	3.7 ± 1.2**	.1 ± .2	.2 ± .1*	.4 ± .2*	.2 ± .1**
1955[1]	86					
1956	85	5.0 ± 1.2**	.1 ± .2	-.2 ± .1	.1 ± .2	.5 ± .1**
1957	89	7.1 ± 1.2**	1.2 ± .2**	-.5 ± .1**	.7 ± .2**	.9 ± .1**
Age of Dam						
2-3 years	130	-4.9 ± 1.0**	-.6 ± .1**	-.2 ± .1**	-.8 ± .1**	-.2 ± .1**
4-5 years[1]	168					
6-7 years	93	3.8 ± 1.1**	.3 ± .2*	.1 ± .1	.4 ± .2*	.1 ± .1
8-9 years	32	2.4 ± 1.6	.1 ± .2	.0 ± .1	.0 ± .2	.0 ± .1
10-14 yrs.	91	-4.4 ± 1.1**	-.3 ± .2	-.2 ± .1**	-.5 ± .2**	-.2 ± .1**
Month of Birth						
January	65	.6 ± 1.1	-.2 ± .2	.1 ± .1	-.3 ± .2	-.1 ± .1
February[1]	220					
March	122	2.0 ± 0.9*	.1 ± .1	.1 ± .1	.2 ± .1	.0 ± .1
April	107	3.1 ± 1.0**	.1 ± .1	.1 ± .1	.2 ± .1	.1 ± .1
Sex of Calf						
Bulls	207	4.2 ± 0.7**	.5 ± .1**	.2 ± .1**	.2 ± .1	.2 ± .0**
Heifers[1]	261					
Steers	46	3.0 ± 1.3*	.5 ± .2**	.1 ± .1	.4 ± .2	.0 ± .1

Table 3 (continued)

Effect	Heart Girth	Round Measure	Circ. of Cannon	Birth Type	Weaning Type	Weaning A.D.G.
Deviation from Base due to:	b ± s_b	b ± s_b	b ± s_b	b ± s_b	b ± s_b	b ± s_b
Year of Birth						
1952	1.0 ± .2**	.7 ± .2**	.20 ± .04**	1.6 ± .2**	.1 ± .2	-.16 ± .04**
1953	1.1 ± .2**	.5 ± .2*	.23 ± .04**	1.0 ± .2**	-.1 ± .2	-.13 ± .04**
1954	.5 ± .2**	1.5 ± .2**	.12 ± .04**	1.2 ± .2**	-.6 ± .2**	-.13 ± .04**
1955[1]						
1956	1.0 ± .2**	.3 ± .2	.12 ± .04**	-.2 ± .2	-.1 ± .2	.17 ± .04**
1957	.7 ± .2**	1.0 ± .2**	.03 ± .04	.1 ± .2	-.7 ± .2**	-.06 ± .04
Age of Dam						
2-3 years	-.5 ± .2**	-.6 ± .2**	-.03 ± .03	-.5 ± .2**	-.5 ± .2**	-.19 ± .03**
4-5 years[1]						
6-7 years	.5 ± .2**	.5 ± .2**	.06 ± .03	.2 ± .2	-.1 ± .2	-.02 ± .03
8-9 years	.4 ± .3	.2 ± .3	.05 ± .05	-.5 ± .3	-.9 ± .3**	-.15 ± .05**
10-14 yrs.	-.5 ± .2**	-.3 ± .2	-.04 ± .03	-1.0 ± .2**	-1.0 ± .2**	-.12 ± .03**
Month of Birth						
January	.1 ± .2	-.4 ± .2*	.10 ± .03**	.2 ± .2	.0 ± .2	-.08 ± .03*
February[1]						
March	.2 ± .2	.2 ± .1	-.00 ± .03	.1 ± .2	-.0 ± .2	.08 ± .03**
April	.3 ± .2*	.3 ± .2	-.06 ± .03	-.1 ± .2	-.5 ± .2**	.02 ± .03
Sex of Calf						
Bulls	.5 ± .1**	.4 ± .1**	.23 ± .02**	.6 ± .1**	-.1 ± .1	.29 ± .02**
Heifers[1]						
Steers	.3 ± .2	.1 ± .2	.23 ± .04**	.6 ± .2*	-.7 ± .2**	.08 ± .04*

1 Base Effect
* Significant at P < .05
** Significant at P < .01

Table 4

Estimates for Constants from Least Squares Analysis, Shorthorn Calves

Effect	Number Calves	Birth Weight	Height at Withers	Depth of Chest	Length of Body	Length of Hips
Deviation from Base due to:		b ± s_b	b ± s_b	b ± s_b	b ± s_b	b ± s_b
Year of Birth						
1952	68	1.2 ± 1.2	-.4 ± .2*	.3 ± .1**	.3 ± .2	-.1 ± .1*
1953	67	-0.2 ± 1.2	-.5 ± .2**	.2 ± .1	-.1 ± .2	-.1 ± .1*
1954	75	-0.8 ± 1.1	-.2 ± .2	.2 ± .1	-.4 ± .2*	-.1 ± .1
1955	110					
1956	70	0.8 ± 1.2	-.0 ± .2	-.1 ± .1	-.0 ± .2	-.3 ± .1**
1957	48	2.5 ± 1.4	-.1 ± .2	-.1 ± .1	-.5 ± .2*	.3 ± .1**
Age of Dam						
2-3 years	84	-4.4 ± 1.0**	-.5 ± .2**	-.2 ± .1**	-.5 ± .1**	-.2 ± .1**
4-5 years	156					
6-7 years	115	1.8 ± 0.9*	.0 ± .1	.1 ± .1	.1 ± .1	.0 ± .0
8-9 years	64	1.2 ± 1.1	.1 ± .2	.2 ± .1*	-.1 ± .2	.0 ± .1
10-14 yrs.	19	2.6 ± 1.8	.8 ± .3**	.3 ± .1*	.6 ± .3*	.2 ± .1*
Month of Birth						
January	104	-0.5 ± 1.0	.1 ± .2	.1 ± .1	-.2 ± .2	.1 ± .1
February	188					
March	91	0.3 ± 1.0	-.1 ± .2	-.1 ± .1	.0 ± .1	-.0 ± .1
April	55	5.6 ± 1.2**	.4 ± .2*	.1 ± .1	.4 ± .2*	.2 ± .1**
Sex of Calf						
Bulls	185	4.2 ± 0.7**	.3 ± .1**	.1 ± .1*	.3 ± .1**	.2 ± .0**
Heifers	207					
Steers	46	2.5 ± 1.2*	.3 ± .2	.1 ± .1	.0 ± .2	.2 ± .1**

Table 4 (continued)

Effect	Heart Girth	Round Measure	Circ. of Cannon	Birth Type	Weaning Type	Weaning A.D.G.
Deviation from Base due to:	b ± s_b	b ± s_b	b ± s_b	b ± s_b	b ± s_b	b ± s_b
Year of Birth						
1952	.8 ± .2**	.2 ± .2	.13 ± .04**	.8 ± .2**	-.5 ± .2*	-. 9 ± .03**
1953	.5 ± .2*	-.3 ± .2	.11 ± .04**	.2 ± .2	-.4 ± .2	-.18 ± .03**
1954	-.2 ± .2	.5 ± .2**	-.01 ± .04**	.7 ± .2**	-.1 ± .2	.05 ± .05
1955						
1956	.0 ± .2	-.2 ± .2	.04 ± .04	.1 ± .2	.3 ± .2	.20 ± .03**
1957	-.1 ± .2	-.4 ± .2	.16 ± .04**	.0 ± .2	-.5 ± .2	-.02 ± .04
Age of Dam						
2-3 years	-.6 ± .2**	-.3 ± .1*	.01 ± .03	-.3 ± .2*	-.4 ± .2*	-.08 ± .03**
4-5 years						
6-7 years	.2 ± .1	.2 ± .1	.04 ± .03	.4 ± .1**	.3 ± .2	.02 ± .02
8-9 years	.3 ± .2	.4 ± .2*	.03 ± .04	.3 ± .2	.1 ± .2	.01 ± .03
10-14 yrs.	.8 ± .3**	.1 ± .3	.01 ± .06	.5 ± .3	-.5 ± .3	-.01 ± .05
Month of Birth						
January	.3 ± .2*	.3 ± .2*	.02 ± .03	-.2 ± .2	-.3 ± .2	-.10 ± .03**
February						
March	.1 ± .2	.2 ± .2	-.08 ± .03*	.2 ± .2	-.0 ± .2	.03 ± .03
April	.8 ± .2**	1.0 ± .2**	-.07 ± .04	.6 ± .2**	-.9 ± .2**	.04 ± .03
Sex of Calf						
Bulls	.3 ± .1*	.3 ± .1**	.26 ± .02**	.4 ± .2**	-.1 ± .1	.23 ± .02**
Heifers						
Steers	-.0 ± .2	.3 ± .2	.21 ± .04**	-.2 ± .2	-1.3 ± .2**	-.06 ± .03

1 Base Effect

* significant at $P < .05$

** significant at $P < .01$

Table 5

R^2-Values and F-Ratios from Least Squares Analysis

Trait	Angus		Hereford		Shorthorn	
	R^2	F	R^2	F	R^2	F
Birth Weight	0.27	12.27**	0.26	12.42**	0.19	7.22**
Height at Withers	0.18	7.16**	0.29	14.42**	0.11	3.70
Depth of Chest	0.24	10.32**	0.22	10.09**	0.11	3.74
Length of Body	0.18	7.07**	0.18	8.03**	0.13	4.66*
Length of Hips	0.22	9.41**	0.38	22.09**	0.20	7.50**
Heart Girth	0.24	10.48**	0.16	6.83**	0.19	6.92**
Round Measure	0.22	9.28**	0.20	8.96**	0.18	6.54*
Circ. of Cannon	0.25	11.19**	0.29	14.51**	0.29	12.28**
Birty Type	0.11	4.04*	0.22	10.14**	0.20	7.42**
Weaning Type	0.14	5.26*	0.13	5.47*	0.15	5.39*
Weaning A.D.G.	0.36	18.05**	0.42	26.34**	0.37	17.77**

steered at midsummer were lighter in weight at birth than were the bull calves, but they were heavier than heifer calves. In steer calves, the constants for linear body measurements seldom approach significance. Bull calves scored somewhat higher in birth type and slightly lower in weaning type than heifer calves. Steer calves were graded approximately one third of a grade, i.e., one grade point below heifer calves at weaning.

For a proper evaluation of the year effect on the birth traits it may be misleading to look only at the significance level of the estimated constants. Apparently, 1955, the randomly chosen base year, was an extreme year, most of the fitted constants deviating from the base in the same direction. Selecting a "typical" or medium year as the base would have been likely to yield far less significance in the year effect which, for the birth traits, would be a more reasonable result than highly significant year differences.

A number of publications have been reported on the effects of year, age of dam, month or birth, sex of calf, and breed on birth weight, preweaning gain, and weaning type. The results found in this study are in general agreement with the reviewed literature. Shelby et al. (1955) reported that year of birth affected the birth weights of 635 Hereford steers only slightly, but that the growth characters were extremely variable in different years. These authors demonstrated a directly proportional relationship between annual rainfall and preweaning gain.

Age of dam was considered by many research workers as the most important source of variation in birth weight and preweaning growth.

Venge (1948) calculated a linear regression of birth weight on weight of dam and suggested that the dam's physiological age has a stronger effect than her weight or size. Rollins and Guilbert (1954) found that calves out of first and second calf cows grew faster from four months to weaning than did calves out of older cows. This effect was attributed to a greater persistency in lactation of young cows.

Thornton (1960) reported that, due to a prolonged gestation period, April calves were heavier at birth than earlier calves. January calves were found to gain slower from birth to weaning as compared to later calves. Lehmann (1959) found in data collected at the Front Royal Beef Cattle Research Station that calves born in April or later scored significantly lower at weaning than did earlier calves. Type scores were not influenced sufficiently by either age of calf or season of birth to be of any practical importance in a large group of calves from Virginia herds under the beef cattle improvement program (Marlowe and Gaines, 1958).

Sex differences were found by practically all investigators dealing with calf birth weights (Dawson et al., 1947; Willard, 1948; Gregory et al., 1950; Koch and Clark, 1955a; Bennett, 1958). Burris and Blunn (1952) attributed 10 percent of the difference between bull and heifer calves to differences in gestation length. A significant effect of sex on preweaning gain was reported by Black and Knapp (1936) and Marlowe and Gaines (1958), but could not be verified by Gregory et al. (1950). The influence of sex on weaning type score was considered negligible by Koch and Clark (1955a) and by Marlowe and Gaines (1958).

The R^2-values in table 5 indicate how much of the variation in all birth and weaning traits expressed as a sum of squares is accounted for by the regression on year, age of dam, month of birth, and sex of calf. The highest R^2-values were found for average daily gain from birth to weaning, ranging from .36 (in Angus) to .42 (in Herefords). On the average, R^2-values were somewhat higher in the Herefords and somewhat lower in the Shorthorn breeds than in the Angus.

C. Means and Standard Deviations:

Table 6 presents the means and standard deviations for all birth and weaning traits, computed from unadjusted and adjusted data. Birth weights, as can be seen from the unadjusted data, were lowest in Angus and highest in Shorthorn, Hereford calves being somewhat lighter than Shorthorn calves. The opposite trend holds true for preweaning gain; Angus calves outgained Hereford calves by .20 pounds and Shorthorn calves by .24 pounds per day.

The breed differences in linear body measurements followed essentially the same pattern as birth weight. Birth type was slightly higher in Herefords than in the other two breeds, while weaning type seemed to follow the same trend as average daily gain.

These results agree fairly well with other reports except that in some other studies Hereford calves were found heavier than Shorthorn calves. Thornton (1960) summarized a number of references on differences in birth weight among the three British beef breeds. Apparently, the

Table 6

Unadjusted and Adjusted Means and Standard Deviations of Birth and Weaning Traits

	Angus		Hereford		Shorthorn	
	unadj.	adj.	unadj.	adj.	unadj.	adj.
Number of Calves	473		514		438	
Birth Weight, lbs.	63.4 ± 8.8	58.4 ± 7.5	68.0 ± 9.5	62.7 ± 7.8	70.0 ± 8.5	67.3 ± 7.2
Height at Withers, in. ..	23.9 ± 1.3	23.8 ± 1.2	24.4 ± 1.3	24.0 ± 1.1	25.6 ± 1.1	25.6 ± 1.1
Depth of Chest, in.	9.4 ± 0.7	9.3 ± 0.6	9.7 ± 0.6	9.7 ± 0.6	10.1 ± 0.6	10.0 ± 0.6
Length of Body, in.	20.8 ± 1.4	20.5 ± 1.3	21.7 ± 1.2	21.3 ± 1.1	22.6 ± 1.1	22.6 ± 1.1
Length of Hips, in.	7.7 ± 0.6	7.4 ± 0.6	8.0 ± 0.6	7.7 ± 0.5	8.1 ± 0.4	8.1 ± 0.4
Heart Girth, in.	26.7 ± 1.4	26.3 ± 1.2	27.3 ± 1.3	26.5 ± 1.3	27.5 ± 1.3	27.1 ± 1.2
Round Measure in.	18.5 ± 1.3	17.7 ± 1.2	19.4 ± 1.4	18.7 ± 1.3	19.7 ± 1.2	19.2 ± 1.1
Circ. of Cannon Bone, in.	4.1 ± 0.3	3.9 ± 0.2	4.2 ± 0.3	4.0 ± 0.2	4.2 ± 0.3	4.0 ± 0.2
Birty Type Score	10.3 ± 1.4	10.1 ± 1.4	10.7 ± 1.4	9.7 ± 1.0	10.3 ± 1.0	9.8 ± 1.0
Weaning Type Score	11.5 ± 1.5	12.3 ± 1.4	11.1 ± 1.5	11.8 ± 1.4	10.9 ± 1.5	11.3 ± 1.4
Weaning A.D.G., lbs.	1.80± 0.25	1.70± 0.20	1.60± 0.31	1.58± 0.23	1.56± 0.25	1.51± 0.2

* Adjusted for year, age of dam, month of birth, and sex of calf

variation between the different stations for the same breed were about as high as the breed differences, but on the average Angus seemed to yield smaller calves than Shorthorn, and Shorthorn calves were outweighed by Hereford calves. The reversed order was found by Gerlaugh et al. (1951) for preweaning daily gain. Angus calves gained 1.80 pounds daily, compared to 1.48 pounds in the Hereford breed.

D. Phenotypic Correlations:

The phenotypic correlations, calculated separately for the Angus, Hereford, and Shorthorn breeds, are shown in Appendix D, E, and F, and in table 8. For those correlations not showing significant breed differences, weighted averages of the three breeds were computed and are presented in table 7. Because of highly significant breed differences in the correlations of average daily gain with height at withers and with weaning type, it was decided to show all correlations involving daily gain in a separate table (table 8). From this table breed differences can be more closely examined.

Correlations between birth weight and all linear body measurements and to a somewhat lesser degree among the body measurements were, on the average, moderately high, ranging from .27 to .78. These correlations, particularly those between birth weight and heart girth, round measure, height at withers, and depth of chest, were interpreted as a reflection of differences between the calves in general size. Circumference of cannon bone seemed to be more independent of the other body measurements, as indicated by lower phenotypic correlations.

Table 7

Phenotypic Correlations (r_{ij}) Among All Birth Observations and Weaning Type Score for Unadjusted* and Adjusted** Data, Weighted Averages of the Three Breeds

	Ht.W.	D.C.	L.B.	L.H.	H.G.	R.M.	C.C.	B.T.	W.T.
Birth Weight	.59 .61	.48 .60	.53 .56	.52 .56	.69 .49	.59 .63	.48 .54	.38 .40	-.05 -.02
Height at Withers		.37 .49	.48 .49	.57 .49	.50 .53	.48 .48	.32 .36	.12 .12	-.19 -.18
Depth of Chest			.47 .45	.30 .41	.59 .52	.49 .50	.43 .40	.35 .28	-.01 -.03
Length of Body				.40 .42	.53 .49	.44 .42	.29 .27	.25 .17	-.11 -.11
Length of Hips					.47 .46	.45 .42	.33 .32	.18 .18	-.13 -.10
Heart Girth						.56 .57	.48 .46	.39 .37	-.06 -.04
Round Measure							.39 .42	.39 .30	-.05 -.07
Circ of Cannon Bone								.36 .33	-.03 .01
Birth Type									.16 .18

* upper lines; ** lower lines

Birth type was significantly correlated with all other observations at birth, the highest relationship existing between birth type and birth weight. The relatively high correlation between birth type and heart girth would be expected because of the close association between birth weight and heart girth. These two correlations indicated that heavier calves were generally favored in type evaluation. The consistently positive relationship between circumference of cannon bone and birth type reflected a preference of the graders for calves with heavier bones.

Round measure and depth of chest had a significant but fairly low association with type at birth, while height and length measurements showed the lowest correlation with type. A possible explanation for the lack of close relationship between type and the skeletal measurements height and length is that, on the one hand, heavier calves, i.e., those that were taller and longer, were preferred in type; on the other hand, compact calves, i.e., those that were heavier relative to their skeletal dimensions, were graded higher than longer legged calves. Apparently, height and length measurements, if taken as the only criteria, did not give any reliable information on birth type.

The correlations between weaning type and all birth observations, except birth type, were generally low and, with the exception of birth type, negative. The height and length measurements at birth had a highly significant negative association with weaning type. Birth type had a highly significant positive association with weaning type, while all other correlations of weaning type with birth weight and body

Table 8

Phenotypic Correlations (r_{ij}) of Preweaning A.D.G. with Birth and Weaning Traits

	Angus		Hereford		Shorthorn	
	unadj.	adj.	unadj.	adj.	unadj.	adj.
Birth Weight	.42	.30	.28	.24	.26	.15
Height at Withers	.33	.33	.35	.25	.15	.04
Depth of Chest	.30	.21	.12	.12	.12	.12
Length of Body	.30	.27	.21	.22	.15	.10
Length of Hips	.34	.24	.30	.17	.10	.05
Heart Girth	.42	.27	.28	.20	.15	.14
Round Measure	.34	.26	.19	.16	.15	.11
Circ. of Cannon Bone	.35	.15	.19	.04	.11	-.06
Birth Type	.13	.06	-.01	-.05	.17	.11
Weaning Type	.24	.32	.36	.42	.51	.55

measurements were essentially zero. None of the statistically significant correlations was high enough to be of any practical use.

Breed differences were indicated for most of the correlations involving average daily gain from birth to weaning (table 8). Correlations were generally higher in Angus and lower in Shorthorn calves than they were in Herefords, as far as birth weight and body measurements were concerned. The opposite order was observed for the association between weaning type and gain, while birth type was essentially uncorrelated with subsequent gain in all three breeds.

Only two sets of correlations, i.e., height at withers and weaning type with average daily gain, showed statistically significant differences between the breeds, but the general trend was very consistent for the other correlations also. None of the birth observations in Shorthorn calves had any predictive value for subsequent gain. In Angus, and to a lesser degree in Hereford calves, there was a definite relationship of birth weight with height at withers and subsequent gain. Length of body and heart girth showed the next highest coefficients of correlation, but the degree of relationship was too low to be of practical importance for an early evaluation of an individual calf.

The phenotypic correlations between weaning type and preweaning average daily gain were .32, .42, and .55 for the Angus, Hereford, and Shorthorn breeds, respectively. Thus, from 10 to 30 percent of the variation in weaning type could be explained by differences in gain from birth to weaning.

E. Multiple Regression of Birth Type, Weaning Type, and Preweaning Average Daily Gain on Body Measurements:

Multiple regression analyses yielded the results shown in tables 9, 10, and 11. The squared multiple correlation coefficients at the bottom of the tables indicate the fraction of the total variance in the dependent trait that is accounted for by the regression on the seven linear body measurements. The absolute size of the b-values is of less interest than their sign and significance level.

Approximately 40 percent of the variation in birth type of Hereford calves could be explained by the regression on the seven body measurements. Depth of chest, heart girth, and height at withers were the most important linear measurements in determining birth type. In Angus and Shorthorn calves, the amount of variance in birth type that could be accounted for by the regression on the body measurements was considerably lower, i.e., 20 and 27 percent, respectively. The difficulty of determining type by objective measurements is obvious because of the variability between breeds. For instance, heart girth was a highly significant factor in determining birth type, but the regression was negative in Herefords, while positive in the other two breeds. Also, circumference of cannon was one of the most important measurements in Angus calves, but of no predictive value in Hereford calves, while the regression in Shorthorns was just significant at the 5 percent probability level.

Multiple regression analysis of weaning type on the linear body measurements showed that the predictive value of body measurements taken

Table 9

Multiple Regression of Birth Type on Seven Linear Body Measurements at Birth

	Angus b-Value	Angus St. Dev.	Hereford b-Value	Hereford St. Dev.	Shorthorn b-Value	Shorthorn St. Dev.
Height at Withers	-0.21	± 0.07**	-2.05	± 0.50**	-0.38	± 0.07**
Depth of Chest	-0.09	± 0.14	6.06	± 0.87**	0.32	± 0.11**
Length of Body	0.02	± 0.06	0.94	± 0.52	-0.01	± 0.06
Length of Hips	0.17	± 0.13	-2.00	± 1.14	0.29	± 0.17
Heart Girth	0.32	± 0.07**	-2.47	± 0.48**	0.42	± 0.06**
Round Measure	0.24	± 0.07**	-0.64	± 0.46	0.14	± 0.06*
Circ. of Cannon	1.09	± 0.30**	-3.10	± 2.32	0.52	± 0.25*
R^2	0.201		0.399		0.273	

Table 10

Multiple Regression of Weaning Type on Seven Linear Body Measurements at Birth

	Angus		Hereford		Shorthorn	
	b-Value	St. Dev.	b-Value	St. Dev.	b-Value	St. Dev.
Height at Withers	-0.24	± 0.07**	-0.24	± 0.06**	-0.29	± 0.08**
Depth of Chest	0.04	± 0.45	-0.09	± 0.11	0.18	± 0.15
Length of Body	-0.14	± 0.06	-0.03	± 0.07	-0.07	± 0.08
Length of Hips	-0.07	± 0.13	-0.11	± 0.15	-0.32	± 0.21
Heart Girth	-0.03	± 0.08	0.10	± 0.06	0.11	± 0.08
Round Measure	0.13	± 0.08	0.19	± 0.06**	-0.03	± 0.08
Circ. of Cannon	0.50	± 0.31	0.41	± 0.30	-0.30	± 0.32
R^2	0.062		0.059		0.062	

Table 11

Multiple Regression of Preweaning A.D.G. on Seven Linear Body Measurements at Birth

	Angus		Hereford		Shorthorn	
	b-Value	St. Dev.	b-Value	St. Dev.	b-Value	St. Dev.
Height at Withers	-0.034	± 0.010**	0.018	± 0.011	-0.013	± 0.054
Depth of Chest	-0.005	± 0.020	0.027	± 0.019	0.025	± 0.093
Length of Body	0.018	± 0.008*	0.031	± 0.011**	0.007	± 0.048
Length of Hips	0.022	± 0.019	0.006	± 0.025	-0.013	± 0.135
Heart Girth	0.013	± 0.011	0.004	± 0.011	0.028	± 0.052
Round Measure	0.008	± 0.010	0.003	± 0.010	0.017	± 0.048
Circ. of Cannon	-0.035	± 0.043	-0.163	± 0.051**	-0.148	± 0.202
R^2	0.138		0.062		0.003	

at birth was essentially zero for weaning type (table 10). The only measurement showing a consistent effect in all breeds was height at withers. Tall calves at birth tended to score slightly lower at weaning.

The value of linear body measurements as predictors of average daily gain from birth to weaning was low in Angus calves and absolutely zero in Shorthorn calves, Herefords being intermediate between the other two breeds (table 11). In Angus, height at withers was positively associated with subsequent growth, but the degree of association was too small to permit any prediction for an individual animal.

A highly significant negative association was found between average daily gain and circumference of cannon bone in Hereford calves, indicating that calves with lighter bones at birth had a better growth potential for the preweaning period. The association between preweaning growth and circumference of cannon was negative and comparatively high in the other two breeds also, but lacked statistical significance.

F. <u>Simple Linear Regression of Birth Type, Weaning Type, and Preweaning Average Daily Gain on Various Ratios of Body Measurements</u>:

The coefficients of determination (r^2-values) in tables 12, 13, and 14 give a measure of the fraction of the total variance in birth type, weaning type, and preweaning average daily gain that can be explained by the different ratios of body measurements.

The first ratio, i.e., height at withers minus depth of chest to height at withers, should give a measure of relative "long-leggedness" of a calf, a measure which would be expected to be negatively associated with type. As shown in table 12, this ratio had a significant influence on birth type, but accounted only for one to eight percent of the variation in birth type.

In the second through seventh ratios, weight, heart girth, and round measure were evaluated relative to size in terms of the two-dimensional skeletal measure, height times length. The ratio of birth weight to length of body times height at withers would be a comparison of volume to two-dimensional expansion. Similarly, heart girth relative to size would indicate width, and round measure would be a measure of fullness of round, or of fleshing of the hind quarters. All these ratios would be expected to be positively associated with type, more so than simple correlations of the same body measurements and birth type, because the factor of absolute size is minimized in the ratios.

Except the third and fourth ratio, all ratios showed statistical significance, but only two of them, i.e., those with birth weight times heart girth and birth weight times round measure in the denominator, were slightly better in determining type than was birth weight alone.

As shown in table 13, all seven ratios of body measurements had a statistically highly significant association with weaning type in Hereford calves, but accounted only for 1.7 to 3.2 percent of the variance in weaning type. The only two ratios that showed high statistical significance for all three breeds, were the two that were nonsignificant in determining birth type, i.e., heart girth to length times height, and

Table 12

Degree of Linear Association (r^2) of Birth Type with Seven Ratios and with Birth Weight

	Angus		Hereford		Shorthorn	
	r^2	F	r^2	F	r^2	F
Ht.W. - D.C. / Ht.W.	.0132[1]	6.28*	.0438[1]	23.46**	.0812[1]	38.54**
B.Wt. / L.B. x Ht.W.	.1240	66.65**	.1170	67.81**	.1557	80.39**
H.G. / L.B. x Ht.W.	.0006[1]	.29	.0004	.18	.0057	2.49
R.M. / L.B. x Ht.W.	.0024	1.12	.0028	1.42	.0033	1.45
B.Wt. x H.G. / L.B. x Ht.W.	.1747	99.70**	.1349	79.83**	.2190	122.28**
B.Wt. x R.M. / L.B. x Ht.W.	.1823	105.00**	.1298	76.37**	.2009	109.64**
H.G. x R.M. / L.B. x Ht.W.	.0584	29.24**	.0460	24.68**	.1053	51.32**
Birth Weight	.1838	106.04**	.1251	73.19**	.1757	92.92**

[1] The linear regression coefficient was negative

* significant at $P < .05$

** significant at $P < .01$

Table 13

Degree of Linear Association (r^2) of Weaning Type with Seven Ratios and With Birth Weight

	Angus		Hereford		Shorthorn	
	r^2	F	r^2	F	r^2	F
Ht. W. - D.C. / Ht.W.	.0077[1]	3.63	.0208[1]	10.88**	.0157[1]	6.94**
B.Wt. / L.B. x Ht.W.	.0140	6.71*	.0291	15.33**	.0073	3.19
H.G. / L.B. x Ht.W.	.0376	18.38**	.0166	8.64**	.0400	18.15**
R.M. / L.B. x Ht.W.	.0420	20.63**	.0316	16.69**	.0224	9.99**
B.Wt. x H.G. / L.B. x Ht.W.	.0036	1.72	.0177	9.25**	.0017	.74
B.Wt. x R.M. / L.B. x Ht.W.	.0043	2.05	.0268	14.11**	.0005	.20
H.G. x R.M. / L.B. x Ht.W.	.0212	10.21**	.0312	16.50**	.0111	4.89*
Birth Weight	.0041[1]	1.92	.0033	1.70	.0051[1]	2.22

[1] The linear regression coefficient was negative

* significant at $P < .05$

** significant at $P < .01$

Table 14

Degree of Linear Association (r^2) of Preweaning A.D.G. with Seven Ratios and with Birth Weight

	Angus		Hereford		Shorthorn	
	r^2	F	r^2	F	r^2	F
Ht.W. - D.C. / Ht.W.	.0042	1.97	.0039	2.02	.0091[1]	4.00*
B.Wt. / L.B. x Ht.W.	.0007	.34	.0053	2.72	.0119	5.26*
H.G. / L.B. x Ht. W.	.0779[1]	39.76**	.0352[1]	18.66**	.0003[1]	.15
R.M. / L.B. x Ht.W.	.0435[1]	21.41**	.0248[1]	13.01**	.0002[1]	.08
B.Wt. x H.G. / L.B. x Ht.W.	.0142	6.77*	.0164	8.54**	.0199	8.85**
B.Wt. x R.M. / L.B. x Ht.W.	.0216	10.41**	.0165	8.61**	.0199	8.85**
H.G. x R.M. / L.B. x Ht.W.	.0036[1]	1.71	.0012[1]	.62	.0056	2.47
Birth Weight	.0901	46.66**	.0557	30.22**	.0214	9.53**

[1] The linear regression coefficient was negative
* significant at $P < .05$
** significant at $P < .01$

round measurement to length times height. Again, the numerical value of the coefficients of determination was too small to be of any practical use for predicting weaning type. Birth weight apparently had no effect on weaning type, as was indicated before from the phenotypic correlations.

The same two ratios that had a consistently positive association with weaning type, showed a highly significant negative relation to preweaning average daily gain of Angus and Hereford calves, with coefficients of determination ranging from .025 to .078 (table 14). When heart girth and round measurement were combined as in the seventh ratio, there appeared to be no association with average daily gain. Birth weight alone had a higher predictive value for preweaning gain than any of the ratios of body measurements, even higher than the complex ratios involving birth weight (ratios V and VI). Birth weight accounted for 9, 6, and 2 percent of the variation in preweaning gain of Angus, Hereford, and Shorthorn calves, respectively.

CONCLUSIONS AND SUMMARY

A. Conclusions:

Since birth type showed only a low association with weaning type and preweaning gain, it is of no practical interest whether or not type at birth can be expressed by certain body proportions, which themselves are not high enough correlated with the two weaning traits to be of any predictive value. The high association between birth weight and the linear body measurements suggests that birth weight is as good a measure of a calf's merit at birth as any other birth observation. Birth weight should be considered a useful selection criterion for Angus and possibly Hereford calves, but not for Shorthorns, except that extremely small calves should not be kept as breeding stock. Neither body measurements nor type at birth can be recommended as selection criteria as their use would not be likely to result in an improvement of the more important weaning traits.

The results of the present study are based on phenotypic relationships between the various traits of beef calves at birth and weaning. Before a final judgment can be given on the value of the birth observations as predictors of future performance, two further studies should be made using the same group of calves: 1. Genetic and environmental correlations should be estimated for the traits correlated phenotypically in the present investigation. 2. The birth traits should be correlated with postweaning growth and type. It is possible that genetic correlations between birth and weaning traits or phenotypic correlations between birth traits and postweaning observations would be higher than those found in this study for phenotypic associations between birth and weaning traits, though at present there is no indication that other correlations should reveal a high value of body measurements at birth as predictors of future performance.

B. Summary:

The data used in this study had been recorded in a group of 1425 beef calves of the Angus, Hereford, and Shorthorn breeds, raised at the Beef Cattle Research Station, Front Royal, Virginia, during the years 1952 through 1957. Included in the study were the following traits: birth weight, seven linear body measurements at birth, type at birth and weaning, and average daily gain from birth to weaning.

Phenotypic correlations were estimated among the birth and weaning traits. Associations between birth weight and the linear body measurements were fairly high, reflecting differences between calves in general size; those among the linear body measurements were generally lower, indicating that linear measurements varied more independently of each other than did birth weight and measurements.

Multiple regression analyses of birth type, weaning type, and preweaning average daily gain on seven linear body measurements showed that from 20 to 40 percent of the variation in birth type could be explained by variation in the linear body measurements, whereas the measurements had essentially no predictive value with respect to preweaning gain and weaning type.

Simple linear regressions of birth type, weaning type, and preweaning gain on seven ratios of body measurements showed that none of the ratios had a practical advantage over birth weight in predicting type or gain.

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APPENDIX A

MATRIX FOR FITTING CONSTANTS, ANGUS CALVES

		Total	52	53	54	55	56	57	2	4	6	8	10	1	2	3	4	1	2	3	B.Wt.	Ht.W.	D.C.	L.B.	L.H.	H.G.	R.M.	C.C.	B.T.	W.T.	A.D.G.
Total		473	42	68	64	92	101	106	104	176	117	50	26	101	240	89	43	179	247	47	30,001	11,324.9	4,463.3	9,829.2	3,628.1	12,647.5	8,754.6	1,918.8	4,874	5,462.4	850.59
Year	52		42	0	0	0	0	0	6	23	10	1	2	1	28	11	2	21	21	0	2,647	989.9	415.1	915.7	317.3	1,143.5	781.7	172.8	453	493.8	76.02
	53			68	0	0	0	0	10	32	18	3	5	2	34	18	14	26	42	0	4,142	1,587.7	650.8	1,429.2	508.7	1,814.8	1,226.7	276.6	678	761.0	120.57
	54				64	0	0	0	23	16	19	1	5	8	25	13	18	18	36	10	4,093	1,522.0	617.0	1,337.6	487.2	1,682.9	1,241.4	257.7	703	743.2	114.17
	55*					92	0	0	30	27	28	1	6	20	49	19	4	35	41	16	5,466	2,193.7	858.0	1,875.0	685.0	2,410.6	1,649.9	369.8	915	1,091.2	162.99
	56						101	0	17	40	19	20	5	27	56	16	2	35	54	12	6,596	2,416.2	970.7	2,067.5	804.2	2,780.6	1,889.5	418.8	1,017	1,188.5	191.02
	57							106	18	38	23	24	3	43	43	12	3	44	53	9	7,057	2,615.4	951.7	2,204.2	825.7	2,815.1	1,965.4	423.1	1,108	1,184.7	185.82
Age of Dam	2								104	0	0	0	0	29	50	18	7	35	54	15	6,136	2,442.0	962.1	2,093.9	769.0	2,711.2	1,891.0	416.3	1,055	1,202.2	176.31
	4*									176	0	0	0	35	94	31	16	55	103	18	11,209	4,207.8	1,660.2	3,655.5	1,350.2	4,720.5	3,252.9	713.1	1,835	2,052.7	317.58
	6										117	0	0	19	59	24	15	59	51	7	7,679	2,825.4	1,117.8	2,487.1	907.0	3,152.0	2,196.7	478.7	1,223	1,363.1	217.47
	8											50	0	12	26	9	3	21	27	2	3,343	1,226.4	476.9	1,051.0	400.1	1,362.5	937.3	205.3	508	563.4	93.64
	10												26	6	11	7	2	9	12	4	1,634	623.3	246.3	541.7	201.8	701.3	476.2	105.4	253	281.0	45.59
Month	1													101	0	0	0	39	51	11	6,490	2,419.0	933.9	2,054.6	760.1	2,702.4	1,839.1	412.6	1,042	1,164.4	177.36
	2*														240	0	0	93	126	21	15,001	5,730.1	2,269.1	4,986.7	1,835.5	6,417.1	4,421.2	969.7	2,440	2,797.7	434.09
	3															89	0	36	42	11	5,621	2,140.4	844.9	1,875.5	696.6	2,368.6	1,671.5	362.3	931	1,030.6	163.64
	4																43	11	28	4	2,889	1,035.4	415.4	912.4	335.9	1,159.4	822.8	174.2	461	469.7	75.50
Sex **	1																	179	0	0	11,911	4,324.5	1,707.5	3,757.2	1,393.3	4,855.2	3,364.0	750.6	1,887	2,040.2	350.70
	2*																		247	0	15,089	5,872.0	2,313.2	5,108.7	1,868.3	6,542.4	4,514.8	975.6	2,498	2,919.7	419.05
	3																			47	3,001	1,128.4	442.6	963.3	366.5	1,249.9	875.8	192.6	489	502.5	80.84

* Base Effect; ** 1, Bulls; 2, Heifers; 3, Steers

APPENDIX B

MATRIX FOR FITTING CONSTANTS, HEREFORD CALVES

		Total	52	53	54	55	56	57	2	4	6	8	10	1	2	3	4	1	2	3	B.Wt.	Ht.W.	D.C.	L.B.	L.H.	H.G.	R.M.	C.C.	B.T.	W.T.	A.D.G.
Total		514	70	90	94	86	85	39	130	168	93	32	91	65	220	122	107	207	261	46	35,157	12,530.3	4,997.5	11,128.5	4,096.4	14,039.4	9,983.6	2,178.5	5,489	5,683.6	321.78
Year	52		70	0	0	0	0	0	36	2	1	3	28	4	21	13	32	34	36	0	4,643	1,656.9	695.7	1,543.2	540.2	1,917.8	1,349.8	298.5	790	773.7	101.22
	53			90	0	0	0	0	23	38	2	3	24	10	25	30	25	41	45	4	6,112	2,165.3	897.0	1,972.8	689.3	2,484.4	1,727.0	390.1	988	1,000.8	138.11
	54				94	0	0	0	14	49	8	1	22	14	33	22	25	40	45	9	6,401	2,286.0	931.5	2,022.7	742.0	2,549.4	1,899.3	399.4	1,061	1,011.4	145.81
	55*					86	0	0	18	18	33	3	14	15	31	25	15	29	49	8	5,600	2,086.5	838.1	1,824.6	662.4	2,295.4	1,619.4	355.1	872	978.0	141.01
	56						85	0	18	38	23	6	0	9	54	19	3	26	45	14	5,949	2,075.0	813.1	1,813.8	698.9	2,349.7	1,625.8	362.1	855	974.2	154.52
	57							89	21	23	26	16	3	13	56	13	7	37	41	11	6,452	2,268.6	822.1	1,951.4	763.6	2,442.7	1,762.3	373.3	923	950.5	141.11
Age of Dam	2								130	0	0	0	0	15	70	19	26	47	67	16	8,387	3,100.2	1,250.7	2,753.3	1,014.8	3,506.2	2,456.4	548.4	1,382	1,432.4	189.43
	4*									168	0	0	0	20	66	38	44	65	86	17	11,728	4,121.1	1,645.6	3,662.5	1,353.0	4,610.7	3,292.3	712.9	1,834	1,908.1	283.75
	6										93	0	0	18	44	27	4	38	47	8	6,761	2,326.7	906.3	2,041.3	764.9	2,572.4	1,840.4	395.7	1,000	1,058.6	159.60
	8											32	0	5	18	7	2	14	16	2	2,334	800.1	306.3	700.8	266.0	891.0	630.6	136.8	327	336.8	49.80
	10												91	7	22	31	31	43	45	3	5,947	2,190.2	388.6	1,970.6	697.7	2,459.1	1,763.9	384.7	946	952.7	139.20
Month	1													65	0	0	0	26	31	8	4,452	1,580.5	632.3	1,387.3	513.7	1,774.0	1,238.2	281.7	708	726.3	98.60
	2*														220	0	0	81	117	22	14,883	5,381.1	2,108.0	4,736.4	1,771.9	5,986.0	4,258.0	928.8	2,309	2,452.8	351.64
	3															122	0	45	67	10	8,414	2,983.5	1,194.8	2,659.6	966.6	3,339.1	2,387.2	516.3	1,307	1,363.5	202.75
	4																107	55	46	6	7,408	2,593.2	1,062.4	2,345.2	844.2	2,940.3	2,100.2	451.2	1,165	1,146.0	168.79
Sex**	1																	207	0	0	14,677	5,097.8	2,037.2	4,514.3	1,672.0	5,718.1	4,076.0	902.9	2,290	2,279.5	362.12
	2																		261	0	17,286	6,301.3	2,517.1	5,618.1	2,055.2	7,066.7	5,022.2	1,076.3	2,706	2,924.7	386.34
	3																			46	3,194	1,139.2	443.2	996.1	369.2	1,254.6	885.4	199.3	493	484.4	73.32

* Base Effect; ** 1, Bulls; 2, Heifers; 3, Steers

APPENDIX C

MATRIX FOR FITTING CONSTANTS, SHORTHORN CALVES

	Total	52	53	54	55	56	57	2	4	6	8	10	1	2	3	4	1	2	3	B.Wt.	Ht.W.	D.C.	L.B.	L.H.	H.G.	R.M.	C.C.	B.T.	W.T.	A.D.G.
Total	438	68	67	75	110	70	48	84	156	115	64	19	104	188	91	55	185	207	46	30,579	11,215.9	4,403.0	9,903.7	3,564.7	12,046.9	8,606.9	1,826.2	4,499	4,765.5	684.58
Year 52		68	0	0	0	0	0	15	27	16	7	3	0	28	23	17	36	32	0	4,858	1,725.4	694.8	1,570.7	548.1	1,913.5	1,351.2	286.9	746	720.6	104.18
53			67	0	0	0	0	17	21	20	7	2	1	24	25	17	32	30	5	4,686	1,693.6	677.7	1,521.1	540.9	1,864.1	1,303.8	281.4	691	708.2	95.68
54				75	0	0	0	11	26	22	14	2	19	28	19	9	31	35	9	5,164	1,918.3	761.4	1,673.7	611.7	2,039.0	1,516.5	307.2	803	821.2	121.11
55*					110	0	0	26	37	24	20	3	39	35	24	12	40	52	18	7,573	2,835.1	1,096.7	2,488.5	901.5	3,005.4	2,162.0	452.1	1,088	1,204.6	168.73
56						70	0	9	26	20	10	5	45	25	0	0	27	33	10	4,867	1,808.8	696.0	1,580.9	557.3	1,922.1	1,358.6	293.3	693	794.4	119.88
57							48	6	19	13	6	4	0	48	0	0	19	25	4	3,431	1,234.7	476.4	1,068.8	405.2	1,302.8	914.8	205.3	478	516.5	75.00
Age of Dam 2								84	0	0	0	0	22	23	20	19	38	37	9	5,551	2,116.8	825.5	1,868.9	673.0	2,269.8	1,629.6	349.6	831	876.2	124.04
4*									156	0	0	0	34	65	37	20	61	78	17	10,899	3,999.3	1,565.5	3,534.4	1,270.2	4,288.4	3,055.1	646.8	1,585	1,708.6	245.00
6										115	0	0	26	55	23	11	54	49	12	8,250	2,949.4	1,161.7	2,618.0	940.0	3,182.1	2,277.6	483.7	1,219	1,266.4	184.61
8											64	0	19	33	9	3	26	32	6	4,505	1,648.7	653.9	1,441.9	522.6	1,769.9	1,273.8	267.0	663	714.1	101.17
10												19	3	12	2	2	6	11	2	1,374	501.9	196.4	440.5	158.9	536.7	370.8	79.1	201	200.2	29.76
Month 1													104	0	0	0	44	45	15	7,114	2,682.5	1,044.2	2,329.1	842.8	2,855.7	2,052.2	434.9	1,027	1,147.4	163.40
2*														188	0	0	77	91	20	13,146	4,814.8	1,888.6	4,245.6	1,536.4	5,142.4	3,647.7	790.8	1,923	2,070.6	296.06
3															91	0	39	46	6	6,263	2,304.6	911.4	2,061.6	732.3	2,498.2	1,788.2	373.0	953	997.1	140.58
4																55	25	25	5	4,056	1,414.0	558.8	1,267.4	453.2	1,550.6	1,113.8	227.5	596	550.4	84.54
Sex** 1																	185	0	0	13,324	4,756.7	1,875.0	4,217.0	1,521.1	5,127.6	3,664.0	795.9	1,949	2,015.1	312.74
2																		207	0	14,041	5,269.1	2,067.5	4,653.9	1,663.7	5,668.1	4,034.2	835.7	2,099	2,294.7	305.67
3																			46	3,214	1,190.1	460.5	1,032.8	379.9	1,251.2	908.7	194.6	451	455.7	66.17

* Base Effect; ** 1, Bulls; 2, Heifers; 3, Steers

APPENDIX D

Phenotypic Correlations (r_{ij}) Among All Birth Observations and Weaning Type Score for Unadjusted* and Adjusted** Data, Angus Calves

	Ht.W.	D.C.	L.B.	L.H.	H.G.	R.M.	C.C.	B.T.	W.T.
Birth Weight	.65 .61	.50 .59	.54 .54	.58 .49	.76 .77	.70 .68	.57 .53	.46 .43	-.14 -.06
Height at Withers		.34 .50	.43 .46	.53 .47	.49 .54	.54 .55	.35 .41	.18 .15	-.22 -.19
Depth of Chest			.45 .41	.38 .42	.60 .59	.52 .54	.47 .41	.24 .23	-.05 -.07
Length of Body				.40 .40	.48 .49	.46 .44	.28 .27	.21 .18	-.18 -.17
Length of Hips					.51 .44	.51 .45	.41 .38	.25 .23	-.14 -.10
Heart Girth						.59 .62	.56 .47	.34 .37	-.12 -.10
Round Measure							.45 .43	.43 .34	-.07 -.05
Circ. of Cannon Bone								.37 .32	-.06 -.00
Birth Type									.20 .26

* upper lines; ** lower lines

APPENDIX E

Phenotypic Correlations (r_{ij}) Among All Birth Observations and Weaning Type Score for Unadjusted* and Adjusted** Data, Hereford Calves

	Ht.W.	D.C.	L.B.	L.H.	H.G.	R.M.	C.C.	B.T.	W.T.
Birth Weight	.56 .59	.41 .62	.53 .60	.48 .47	.62 .80	.55 .61	.42 .58	.30 .35	.02 .06
Height at Withers		.27 .46	.52 .53	.58 .43	.48 .49	.46 .42	.28 .33	.08 .11	-.15 -.15
Depth of Chest			.49 .50	.13 .41	.56 .60	.45 .50	.47 .44	.38 .27	.05 .02
Length of Body				.40 .44	.55 .50	.46 .42	.35 .33	.26 .16	-.03 -.03
Length of Hips					.44 .43	.44 .42	.26 .31	.05 .09	-.06 -.05
Heart Girth						.55 .56	.53 .48	.36 .31	.03 .02
Round Measure							.40 .43	.34 .25	.03 .09
Circ. of Cannon Bone								.46 .40	.04 .05
Birth Type									.19 .20

* upper lines; ** lower lines

APPENDIX F

Phenotypic Correlations (r_{ij}) Among All Birth Observations and Weaning Type Score for Unadjusted* and Adjusted** Data, Shorthorn Calves

	Ht.W.	D.C.	L.B.	L.H.	H.G.	R.M.	C.C.	B.T.	W.T.
Birth Weight	.58 .62	.55 .58	.52 .53	.49 .52	.69 .78	.53 .60	.46 .49	.40 .42	-.05 -.07
Height at Withers		.52 .52	.48 .48	.60 .59	.55 .58	.46 .47	.34 .36	.12 .11	-.19 -.21
Depth of Chest			.48 .44	.41 .41	.63 .59	.49 .45	.36 .35	.42 .33	-.04 -.04
Length of Body				.40 .42	.56 .49	.40 .41	.23 .21	.28 .20	-.13 -.12
Length of Hips					.45 .50	.39 .39	.33 .29	.24 .22	-.21 -.17
Heart Girth						.55 .54	.40 .43	.49 .44	-.09 -.06
Round Measure							.33 .41	.42 .32	-.12 -.08
Circ. of Cannon Bone								.27 .28	-.08 -.01
Birth Type									.07 .08

* upper lines; ** lower lines

ABSTRACT

Birth weight, seven linear body measurements at birth, type at birth and weaning, and average daily gain from birth to weaning were recorded in a group of 1425 beef calves of the three British beef breeds, raised at the Beef Cattle Research Station, Front Royal, Virginia, during the years 1952 through 1957. Phenotypic correlations between birth weight and body measurements were fairly high, ranging from .49 to .78, indicating that both, weight and measurements, are largely determined by general size. The phenotypic correlations among the body measurements were moderately high, ranging from .27 to .57. Birth type had a significant but low positive association with the other birth observations in all three breeds. Weaning type was negatively or not at all correlated with birth weight and body measurements, while birth type had a low significant positive correlation with weaning type. Breed differences were found for correlations involving average daily gain; those with birth weight and body measurements were highest in Angus and lowest in Shorthorn calves, while the opposite was true for the relationship between preweaning gain and weaning type. Birth type was essentially uncorrelated with subsequent gain. Multiple regression analyses of birth type, weaning type, and preweaning average daily gain on seven body measurements at birth, as well as simple linear regressions on seven ratios of certain body measurements revealed that the predictive value of body measurements at birth is not high enough to give a reliable early indication of a calf's merit.