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DIVISION OF RANGE ANIMAL HUSBANDRY

THE RELATION OF BODY SHAPE OF FEEDER STEERS TO RATE OF GAIN, TO DRESSING PER CENT, AND TO VALUE OF DRESSED CARCASS

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Individual gains, dressing percentages, and commercial value of the carcasses of steers at the end of the fattening period can be predicted with only slight success at the beginning of the feeding period. Even with careful measuring and weighing of the animals as was done in this experiment, the shape and size of the feeder steer indicated only to a slight extent its desirability at the end of the feeding period.

There is a slight tendency for long-bodied, tall steers with big middles but small flanks and thin loins to make faster gains. Steers that are already fleshier than the others when feeding begins and that are heavy in proportion to their bony measurements are somewhat apt to dress the highest at the end of the feeding period. The most desirable cuts of meat tend to come from steers which are large in their fleshy measurements but small in most bony measurements at the beginning of the feeding period.

Conformation is often the only basis available for judgment and of course should be given some consideration at all times. However, the data indicate that no score card or standard based on conformation could ever be so accurate that the future performance of individual steers could be predicted from it with but few mistakes.

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THE RELATION OF BODY SHAPE OF FEEDER STEERS TO RATE OF GAIN, TO DRESSING PER CENT, AND TO VALUE OF DRESSED CARCASS

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The idea that there is an intimate relation between the outward appearance or conformation of an animal and its inward physiology or functioning is old and widespread. If such relations exist and are close it should be possible, by paying proper attention to external conformation, to achieve considerable success in selecting animals which would function as desired. As applied to domestic animals these relations in one way or another are the basis of much of what is taught in stock judging. Many of the objectives of stock judging, particularly in the fat classes, rest on an association between outward conformation and present yields or proportions of cuts rather than on a close relation between present conformation and future anatomy or future functioning.

Such agreement of opinion as has been reached in regard to what constitutes an ideal type of individual has come about largely through the unorganized exchange of personal experience of breeders and judges. Judging standards have changed from time to time and one cannot often be sure in any one case whether the change was an improvement or the reverse. As particularly vivid illustrations of this may be cited the escutcheon or "milk mirror" which came into much prominence in the judging of dairy cattle from sixty to thirty years ago but has now gone back to comparative obscurity, and the changes in the type of swine preferred by judges at the leading shows from 1910 to 1925. There has been little systematic collection and analysis of observations on large groups of animals to determine objectively what type of animal would most nearly fulfill the desired purpose.

This Bulletin presents the results of some studies made at the Texas Station on the relation between present conformation and future performance in beef steers, and is an extension of studies reported in Bulletin 385. The specific problem was to find what conformation in feeder steers, as indicated by measurements made at the beginning of the feeding experiment, was associated with the ability to make large gains, with a high proportion of dressed meat to the live weight at the end of the feeding experiment and with a dressed carcass which would be highly esteemed by the meat trade.

PREVIOUS WORK

No extensive study of the relation between body measurements of steers and their subsequent performance in the feed lots or at slaughtering time has come to our attention. Several short studies of the changes in average measurements during fattening have been published, usually incidental to

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some major objective of a feeding trial. Two Wyoming bulletins (3, 4) dealt primarily with the relation of actual measurements to the thing which the live stock judge has in mind when he speaks of "type," so far as type can be expressed in a series of grades from very low-set to very rangy.

Severson and Gerlaugh published in 1917 "A statistical study of body weights, gains, and measurements of steers during the fattening period" (13). They calculated the simple correlation coefficients between a large number of body measurements and the gains which the steers subsequently made. Those correlation coefficients were calculated without any correction for heterogeneity of data and probably would have been somewhat higher if such corrections had been made. Nearly all the correlations were small. No attempt was made to combine the simple correlations into a multiple correlation so as to determine whether each measurement had a relation to gain largely independent of that involved in other measurements or whether the different measurements were various expressions of nearly the same attribute of the steers so far as each showed any relation to gain.

MATERIAL USED IN THIS STUDY

The data studied here consist of various measurements and performances of 241 steers divided among 25 different lots which were fed out in the feedlots at Substation No. 7 near Spur, Texas, during the period of 1922-1929. The first 19 lots are described in some detail on pages 7 to 12 of Bulletin 385 of the Texas Station. The remaining six lots were of similar breeding and included the steers born in 1927 and in 1928.

There was no culling or selection among the steers except that nine which entered the feedlot were discarded because each made a gain which was less than the average gain of the lot in which that particular steer was fed by at least as much as three times the standard deviation of the gains of his lot mates. It is probable that in every such case there was something genuinely wrong with the health of the abnormal steer although that something was not visible when the feeding experiment was begun and in some cases was not definitely identified even by the end of the experiment.

Only four lots of steers were not bred at Substation No. 14. In most lots all of the steers in a single lot were sired by the same bull, that is, were half brothers through their sire and in some cases were slightly related through their dams. None of the steers were inbred. Because the steers within most lots were half brothers to each other, each lot was more uniform genetically than is usually the case with experimental cattle. Nevertheless the standard deviations were large enough that any very important or universal relation between conformation and performance should have been visible in the data, even though it might not have been quite as large here as it would have been among a group of steers all belonging to the same herd but not otherwise related.

METHOD OF CALCULATION

Each lot was treated as a unit in the calculations. The correlation coefficients were calculated by the ordinary product moment method, using for convenience the form outlined by Wallace and Snedecor (14). Standard deviations wherever mentioned are based on the n-1 formula, which involves the idea of "degrees of freedom."

After the primary correlation coefficients were thus calculated they were averaged together by Fisher's Z-method (2). A detailed example of this method of averaging is shown on pages 856 and 857 of Volume 42 of the Journal of Agricultural Research (6).

Homogeneity of Correlations

Various tests were applied to see whether the calculated correlations were appreciably different for steers of the three different kinds of breeding, for steers born in different years, for steers fed in different seasons, or for steers of different ages and hence of different initial weights.

The average correlations for two-year-old steers were based on but 16 degrees of freedom, those for yearlings were based on 64 degrees of freedom, and those for calves were based on 86 degrees of freedom. In comparing these averages there are 1424 comparisons between two average values of Z. Only 28 (2%) of these comparisons showed differences in Z larger than twice their standard errors. Only 5 of the comparisons (1/3 of 1%) showed differences in Z larger than three times their standard error. Such differences are well within the limits of sampling errors. On account of these findings it is not thought that combining the correlations calculated on steers of the three different ages introduced any material error. If there was any general difference at all the correlations were highest for the yearlings and lowest for the two-year-olds.

Similar tests seemed to show no real difference between the correlations obtained in the five different feeding seasons. However, when the correlations were compared according to the breeding of the steers it was found that the correlations generally existing among the back-crosses were lower than in the other groups. This may be interpreted in two ways: (a) as evidence of the "disharmonic" crossing about which biologists are in dispute (1, 12) or, (b) as caused by the back-crosses having been more uniform in age and size within each lot than the other steers were. Table 7 shows that the back-crosses were distinctly less variable in weight and in nearly all measurements than the other groups. For this reason correlations calculated upon them are less affected by differences in general size than are the correlations calculated in the other groups and hence are smaller. In the subsequent calculation of multiple correlations compensation for this is made by including variables such as initial weight, heart girth, body length, chest depth, etc., which also express differences in general size. The conclusions thus obtained approximate those which would have been obtained by the use of ratios, from which the effects of differences in general size have been largely cancelled. Therefore it is believed that the conclusions subsequently drawn are not biased by including, in a single average, correlations calculated on the small back-cross group even though these appear to have been really a little smaller than similar correlations calculated on the other steers.

MEASUREMENTS USED

Twenty three different measurements were studied. They are described in detail in Bulletins 385 and 409 of the Texas Station. Figures 1 and 2 show the location of 17 of these measurements. The other six are described on page 22 of Texas Station Bulletin 409.

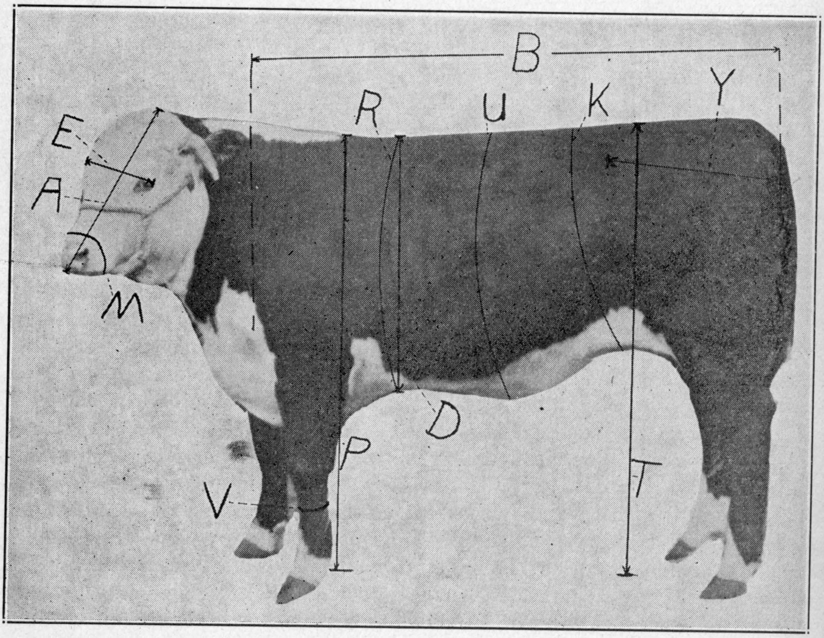

Fig. 1—Side view of Hereford steer showing the location of the various measurements studied. A, Length of head. B, Length of body. D, Depth of chest. E, Width at eyes. K, Flank girth. M, Muzzle circumfrence. P, Height over withers. R, Chest girth. T, Height over hips. U, Paunch girth. V, Cannon circumference. Y, Length of Pelvis.

The instruments used in taking measurements are shown in Figure 3. The error in taking a single measurement such as these has been studied on dairy cattle (9) and found to be about one or two per cent of the mean measurement in most cases. It was certainly a little larger than that on these steers, since many of these were rather wild. Each measurement was taken three times, several other different measurements being taken between repetitions, so as to give the steer opportunity to change positions. The average of the three measurements was used in subsequent calculations.

Besides the measurements there were for each steer initial and final weights (each of which was the average of weights read to the nearest pound or the nearest two pounds on three consecutive days), warm dressed

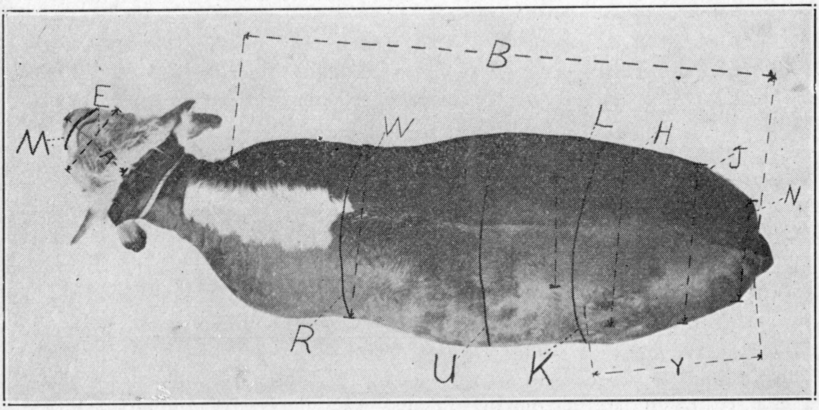

Fig. 2—Top view of Hereford steer showing the location of the various measurements studied. A, Length of head. B, Length of body. E, Width at eyes. H, Width at hooks. J, Width at pelvis or thurls. K, Flank girth. L, Width at loin. M, Muzzle circumference. N, Width at pin bones. R, Chest girth. U, Paunch girth. W, Width of chest. Y, Length of pelvis.

carcass weight (to the nearest pound), appraisals of the commercial worth of the dressed meat (made independently by three or more salesmen for

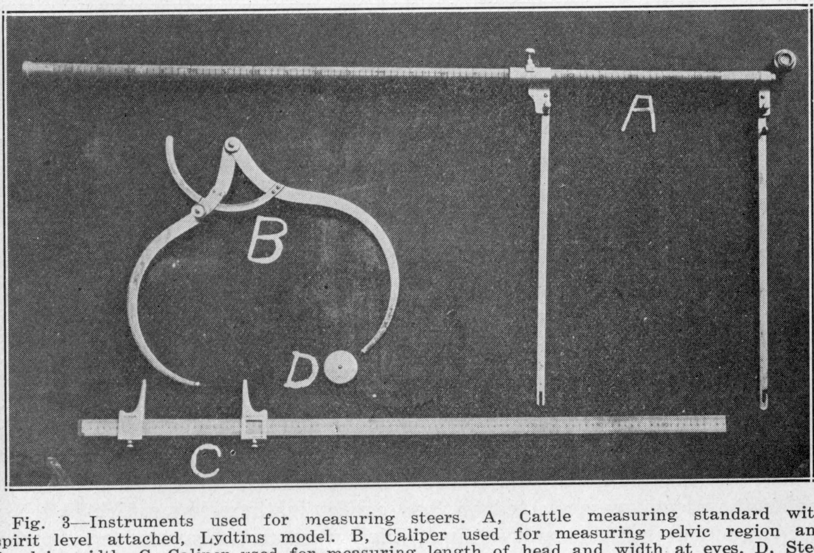

Fig. 3—Instruments used for measuring steers. A, Cattle measuring standard with spirit level attached, Lydtins model. B, Caliper used for measuring pelvic region and for loin width. C, Caliper used for measuring length of head and width at eyes. D, Steel tape used for measuring girths and circumferences.

all except the 1922 and 1923 steers, which were appraised by only one man), and weights of the caul and ruffle fat (to the nearest tenth of a pound).

Combinations and ratios of these primary observations were used as variables in the following cases:

1. Gain=Final feedlot weight — Initial feedlot weight
2. Dressing per cent= $\frac{\text{Warm carcass weight}}{\text{Final feedlot weight}}$
3. Meat value per steer=(Appraised price of meat)×(Warm carcass weight)
4. Live meat value per pound= $\frac{\text{Meat value per steer}}{\text{Final feedlot weight}}$
5. Estimated fatness=
$$\frac{9.073\ (\text{Caul fat}) + .936\ (\text{Warm carcass weight})}{\textbf{Final feedlot weight}} - .4496$$

The equation for estimating fatness was derived from a former study (5). The figure obtained by this equation when multiplied by 100 expresses the estimated percentage of the steer's finad feedlot live weight which is fat, in the chemical sense of the word. In applying this equation to these data both caul fat and ruffle fat were included by using instead of the individual caul fat the following term:

$$\frac{(\text{Individual caul fat} + \text{Individual ruffle fat}) \times (\text{Total caul fat for that lot})}{(\text{Total caul fat for that lot}) + (\text{Total ruffle fat for that lot})}$$

This was done so as to utilize both caul and ruffle fat in estimating fatness and to minimize errors arising from caul variations not directly related to fatness. No equation was available for including both caul and ruffle directly; so this was done indirectly by substituting for the actual caul fat the above term, which expresses the combined caul and ruffle fat for the individual steer reduced to about the magnitude of the caul fat alone by being multiplied by the ratio of the total caul fat for that lot to the combined total of caul and ruffle fats for that lot.

Twelve of the measurements and the warm dressed carcass weights besides the feedlot weights were taken on all 241 steers. Four more measurements (cannon circumference, pelvis length, pelvis width, and width at hooks) and carcass appraisals and caul and ruffle weight were taken on all steers born after 1921 (218 head). Width at pinbones was not taken on the 1921 steers and was inadvertently omitted for the 1924 and 1925 steers also. Elbow and knee heights and the sternum heights were taken on less than half the steers. Measurements were taken the same week the steers were started on feed except in three lots which had been measured two months earlier and which were not measured again when the feeding experiment began.

RESULTS

Biometric Relations Between Initial Weight, Gain, Final Weight, Carcass Weight, and Dressing Per Cent

The relations between these variables are shown in Figure 4 drawn according to Wright's method of path coefficients (15). The numbers shown in Figure 4 are standard regression coefficients except that the +.32 between initial weight and gain is a primary correlation coefficient. Three of the variables pictured, initial, final, and carcass weights, are observed directly from the data. Gain and dressing per cent are rigidly determined by the observed three. "Other" represents all factors other than initial weight and gain which affect the weight of the dressed carcass.

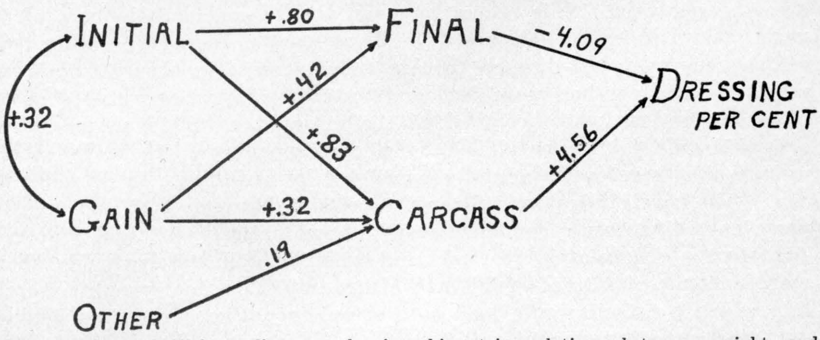

Fig. 4—Path coefficient diagram showing biometric relations between weight and dressing per cent.

Since the relations between initial weight, gain, and final weight are purely additive, the multiple correlation between initial weight and gain as independent variables and final as the dependent should be unity. Actually this is 1.02 when calculated from these average coefficients where slight discrepancies have crept in from the Z-method of averaging and correcting for the bias of small numbers.

The standard regression coefficients from initial weight to dressing per cent and from gain to dressing per cent are +.51 and —.17 when calculated directly and are +.51 and —.24 when calculated indirectly from the diagram in Figure 4. The discrepancy is largely due to the pronounced multiplicative relations existing between final weight, carcass weight, and dressing per cent, along with the very high correlation between final weight and carcass weight. Ninety-six and four-tenths per cent of the observed variance in carcass weight would disappear if all the steers weighed the same amount at the start and gained the same amount. The value of the standard regression coefficient from "other" to carcass weight is deduced from the difference. Only 23 per cent of the observed variance in dressing per cent would disappear if initial weight and gain were alike for all steers.

The following conclusions seem justified by these quantitative relations:

1. Initial weight is more important than gain in predicting variations in final weight, carcass weight, and dressing per cent. This does not have a fundamental physiological significance since the relative importance of the two is influenced by the range of initial weights among the steers within each lot. Initial weight would appear less important if the initial weights had been less variable and the range in gain had remained the same. The range in initial weights within each lot was not extreme in these experiments (see Table 7). It corresponds to a coefficient of variation of about 11 per cent to 14 per cent. Hence the effect of range in enhancing the apparent importance of initial weight is no larger in these data than it is in the usual feeding experiment.

2. Gain counts for more with final weight than with carcass weight or dressing per cent. This seems to mean that a considerable part of the variations in observed gain are "fill" or at least an increase in other parts of the body than the dressed carcass. An increase in observed gain will result if the steer has more feed and water in him when weighed on the final day or less when weighed on the initial day. Such an increase in observed gain is not paralleled by a corresponding increase in carcass weight and therefore is actually paralleled by a decrease in dressing per cent. The barely negative primary correlation between gain and dressing per cent is therefore a combined result of two entirely different processes. The first is the relation just pictured whereby gain automatically shows more extreme effects of "fill" than either initial or final weights, a relation which by itself would lead to a strong negative correlation between gain and dressing per cent. Second, in so far as observed gain does represent a genuine gain in fat and other material which remains on the carcass, just so far is gain positively associated with dressing per cent.

Presumably the effects of "fill" on observed gain and in modifying the relation between gain and dressing per cent would be less important in long feeding periods than in these periods where the steers were fed about 120 days or a little less. In spite of that consideration, it does seem odd that gain as actually figured from the observed weights doesn't really mean increase in the weight of carcass more than it seems to.

The influence of "fill" is surprisingly large in view of the findings of an earlier study of the importance of day-to-day fluctuations in the live weights of cattle (8).

Perhaps a clue to this apparent discrepancy is furnished by Maymone and Sircana (10), who reported evidence of considerable cyclical variation in the weights of cattle of such a nature that the weights would increase over a period of several days and then would decrease over a period of several days. Such variations with a cycle more than two or three days in length would not have been found in our study of the accuracy of cattle weights. If these cyclical variations are of considerable importance, then the findings of the present study that differences in "fill" are so important in explaining the differences between gains made by different individual steers is less surprising. If differences in "fill" really are as important as the present data indicate, then the variability **in gains of actual flesh** is less than the variation **in observed gains.** If this is generally true and important, then individual animals should exhibit less variation in their ability to utilize feed as measured by respiration calorimeter trials than they do in individual feed-lot gains.

Relation of Measurements and Initial Weight to Gain

Table 1 shows the average correlation coefficients for all variables which were observed on all steers. The sampling errors are equivalent to those from a single lot of 169 steers. For the smaller correlations the probable error of each is in the neighborhood of .04 to .06. For this reason the correlation coefficients are presented only to the second figure. In all calculations they were carried out to three decimal places.

The correlations between one measurement and another prevailingly range from a little above .60 to a little above .80. Those involving chest width are a little smaller than those involving the other measurements. Likewise the correlations between a measurement and the three directly observed weights are prevailingly high. Most of those are above .70 and some are nearly as high as .90. These generally high correlations largely reflect differences between these steers in general size. On the other hand the correlations between the measurements or the weights and gain or dressing per cent are prevailingly low, most of them ranging from about .15 to a little above .40. Only one correlation out of the 136 is negative and that one is not statistically significant.

The regularity and size of the correlations between various measurements and gain or dressing per cent, suggest that there is a significant but small correlation between gain or dressing per cent and general size but that there may be no specific correlation between gain or dressing per cent and a particular shape or ratio of a measurement to general size. (The data studied were measurements instead of ratios or proportions, but the inclusion of several measurements in a multiple correlation analysis gives practically the same information about them as if the various possible ratios between them had been studied directly). If this were so, the inclusion of each measurement along with initial weight as independent variables in a multiple correlation with gain or dressing per cent as the dependent variable would raise the correlation but little over what it was when the measurement was left out but initial weight was used as a measure of general size. When this was done, only three of the 12 measurements made contributions as large as .01 to the squared multiple correlation coefficient where gain was the dependent variable.

Similarly only 5 of the 12 measurements added as much as .01 to the squared multiple correlation coefficient where dressing per cent was the dependent variable. Only 4 of the 12 measurements added as much as .01 to the squared multiple correlation coefficient when each measurement in turn was studied along with initial weight and gain as the independent variables and dressing per cent as the dependent variable.

Table 1—Average primary correlations (All Steers. 166 degrees of freedom)

Variable	B	D	E	H	J	K	L	M	R	S	T	F	C	I	G	%
Head length (A)	.68	.79	.73	.72	.75	.71	.66	.73	.81	.60	.50	.71	.71	.77	.22	.38
Body length (B)		.73	.68	.69	.72	.68	.71	.71	.74	.62	.48	.79	.79	.83	.38	.33
Chest depth (D)			.74	.76	.78	.74	.73	.72	.88	.69	.54	.77	.76	.84	.25	.31
Eye width (E)				.59	.61	.66	.65	.73	.76	.62	.52	.72	.70	.80	.24	.29
Wither height (H)					.90	.65	.65	.62	.71	.52	.42	.71	.70	.72	.33	.35
Hip height (J)						.65	.67	.64	.75	.54	.46	.69	.68	.73	.28	.36
Flank girth (K)							.72	.65	.82	.83	.58	.78	.78	.84	.23	.41
Loin (L)								.65	.77	.67	.57	.71	.73	.79	.15	.42
Muzzle (M)									.76	.61	.47	.71	.72	.78	.20	.38
Heart (R)										.76	.71	.84	.81	.89	.27	.47
Paunch (S)											.61	.78	.75	.82	.29	.31
Chest width (T)												.63	.63	.66	.20	.35
Final weight (F)													.98	.93	.67	.36
Carcass (C)														.93	.59	.56
Initial (I)															.32	.45
Gain (G)																—.01

These findings tend to confirm the idea that much of the primary correlation of each measurement with gain or dressing per cent is the effect of general size rather than a relation with that specific measurement.

Table 2 shows (translated into the familiar form of a score card) the standard regression coefficients for several different combinations of measurements with gain as the dependent variable.

The first column in Table 2 shows the result when all 12 measurements are included with initial weight. Even a superficial examination of column one indicates that the two head measurements and the width of chest are of little importance. When they are omitted the figures in the second column are obtained. When the three smallest of these (except for initial weight) are omitted the figures in the third column are obtained. These indicate that heart girth and initial weight could both be omitted without much loss in the multiple correlation coefficient. The fourth column shows the result. The remaining five variables between them express, almost as well as when initial weight and heart girth were included, things in those two variables that were associated with gain.

The figures for the last column in Table 2 show the evidence bearing on the fairly common belief that a steer with a short, wide head will be a good "doer." Height at withers is included with the two head measurements in order to eliminate as much as possible of the effects of general size. The multiple correlation obtained by including all three is only a little larger than that obtained with wither height alone (+.327). When wither height is left out the multiple correlation between the two head measurements and gain is only a little more than half as much as the simple correlation between gain and initial weight and the sign of the head length regression is reversed. In short the two head measurements either as dimensions or as ratios indicate practically nothing about gain.

For most of the variables shown in the first four columns of Table 2 the limits of statistical significance lie somewhere around the magnitude of a score of 6 to 9. Scores much smaller than this might be expected to vary or perhaps even to have reversed signs in other data.

When we try to visualize the kind of steer which is demanded for maximum gain we see essentially a long-bodied tall steer with a big paunch but narrow loin and small flank girth. The author interprets that to be related to the steer's anatomy and physiology in the following way: A long-bodied tall steer would be one with a large frame. A large paunch girth would also indicate large frame and perhaps in addition much room for digestive organs. A narrow loin would indicate a steer in thin flesh and therefore ready to make rapid gains. A small flank girth at the beginning of the experiment would indicate a steer carrying little if any "fill." Such a steer would be in excellent condition to make large gains, especially since non-carcass increases in live weight play a considerable part in observed gains. It is of secondary importance that the steer to make maximum gain should be one with a small muzzle, a shallow

Table 2—Score Card for Maximum Gains

Measurement or weight desired	Points to be allotted in various combinations				
	All twelve measurements and initial weight	Nine most important Measurements and initial weight	Six most important Measurements and initial weight	Five most important measurements	Head Measurements and wither height
Initial weight, large (I)	0.6	1.2	1.9	omitted	omitted
Head, short (A)	2.6	omitted	omitted	omitted	20.2
Body, long (B)	16.7	17.2	24.4	25.5	omitted
Chest, shallow (D)	6.0	6.5	omitted	omitted	omitted
Head, wide at eyes (E)	1.4	omitted	omitted	omitted	20.9
Tall at withers (H)	16.0	16.2	14.5	15.7	58.9
Short at hips (J)	7.1	7.8	omitted	omitted	omitted
Small flank girth (K)	9.2	10.0	14.3	14.7	omitted
Narrow loin (L)	12.5	12.7	22.0	22.9	omitted
Small muzzle (M)	6.2	6.6	omitted	omitted	omitted
Large heart girth (R)	9.9	9.7	2.8	omitted	omitted
Large paunch girth (S)	11.5	12.0	20.1	21.2	omitted
Wide chest (T)	0.1	omitted	omitted	omitted	omitted
Multiple correlation coefficient	.514	.512	.483	.482	.338
Portion of variance in gain which would remain if all the named variables were perfectly controlled	73.6%	73.8%	76.7%	76.7%	88.6%

chest, a large heart girth, and not tall at hips. These secondary points are on the border-line of statistical significance, or near it.

Even when all these measurements or proportions between them are considered, little control over the rate of gain is achieved. If these steers had been identical in initial weight and in all 12 measurements, the variance in gains would still have been nearly three-fourths as large as it actually was. Large but thin steers tend to gain rapidly, but there is not much other association between conformation and rate of gain. High-gaining steers may differ widely in conformation and steers identical in conformation may vary widely in the rates at which they gain.

Miscellaneous Measurements and Gains

Four measurements (cannon circumference, pelvis width, pelvis length, and width at hook bones) were not taken on the 1921 steers. When these four measurements together with initial weight are used as the independent variables and gain as the dependent variable, the multiple correlation obtained is only slightly larger than that obtained with initial weight by itself. Cannon circumference is the most important of the four and such little influence as it does have is positive. Pelvis length has a slight negative association.

The correlations involving width at pon-bones rest on only 111 degrees of freedom. It has a negative influence on gain when placed in a multiple regression equation along with initial weight as the other independent variable. The multiple correlation involving these two is very distinctly increased by the inclusion of pin-bone width. Width at pin-bones is a measurement much influenced by fatness. Probably its negative association with gain means that those steers with the wider pin-bones in proportion to initial weight were already the fatter and therefore not in condition to gain rapidly.

The heights at sternum, elbow, and knee were taken only for the steers born in 1922, 1923, 1927, and 1928. When the net regression coefficients were tested for their statistical significance it developed that knee height and elbow height were significant. Maximum gains were obtained where elbow height was large but knee height was small. The sternum heights were either insignificant or nearly so.

Body Measurements and Dressing Per Cent

Table 3 shows the standard regression coefficients for various combinations of measurements where dressing per cent was used as the dependent variable. As in Table 2, these regression coefficients are expressed in the form of a score card being in proportion to the actual coefficients but so adjusted that they will add up to 100 per cent. The inclusion of all 12 measurements besides initial weight and gain leads to a control of only about one-third of the variance in dressing per cent. Gain of course was unknown when the steers went on feed. For that reason it is omitted from the second combination shown in Table 3. The degree of control is practically the same in the second combination as in the first and the scores are changed but little. Six of the measurements shown in the second

Table 3.—Score card for maximum dressing per cent

Measurement or weight desired	Points to be allotted in various combinations			
	All twelve measurements and initial weight and gain	All twelve measurements and initial weight	Six best measurements and initial weight	Three best measurements and initial weight
Initial weight, large	21.5	21.1	26.5	25.9
Gain, small	4.5	omitted	omitted	omitted
Head, long	1.2	1.5	omitted	omitted
Body, short	4.6	6.8	6.0	omitted
Chest, shallow	18.6	18.1	18.1	27.2
Head, narrow at eyes	7.5	7.5	7.9	omitted
Tall at withers	5.4	3.2	omitted	omitted
Short at hips	.8	.1*	omitted	omitted
Large flank girth	2.3	3.3	omitted	omitted
Wide loin	3.6	5.4	6.8	omitted
Large muzzle	2.1	2.7	omitted	omitted
Large heart girth	18.7	18.7	23.1	34.1
Small paunch girth	9.2	10.3	11.6	12.8
Wide chest	trace	1.3*	omitted	omitted
Multiple correlation coefficient	.604	.591	.579	.550
Portion of variance in dressing per cent which would remain if all the named variables were perfectly controlled	63.5%	65.0%	66.5%	69.8%

*Direction opposite to that indicated in the first column.

combination have coefficients so small that they are certainly not significant in the statistical sence. When they are omitted and the results re-calculated the figures for the third combination are obtained. Three of these six seem to be less important than the other three and when they are omitted the figures shown in the last column of Table 3 are obtained. These figures show nearly as much control over variability in dressing per cent as do the figures where all 12 measurements and initial weight and gain were included.

When we try to visualize what manner of steer would satisfy this objectively determined score card we see that it calls first of all for a steer with a large heart girth but a shallow chest, a large initial weight and a small paunch girth. The large heart girth in spite of a shallow chest means a steer with a large spring of ribs (large effective chest capacity) and perhaps carrying a considerable amount of fat, which would round out and increase the measurement of heart girth without affecting the measurement of chest depth. Large initial weight, the measurements being also taken into account, would indicate a heavier steer for the same size of frame or a steer which has made a better growth of flesh in its early life and presumably is already fatter. A small paunch girth may merely mean a small amount of digestive organs and therefore less non-carcass weight at slaughtering time. A narrow head is of minor importance. Just why it should be conducive to a high dressing per cent is not clear, but the net regression coefficient is about twice its standard error and therefore seems to deserve some confidence or at least warrants attention in future studies of this kind. Of doubtful statistical significance are the requirements that the steer should be short-bodied and have a wide loin. Wide loin is readily understandable since width at loin, better than most measurements, reflects differences in fatness at the beginning of the experiment. Much of the differences in fatness already present at that time would still be present at slaughtering time. A short body would presumably mean less room in the middle for digestive organs and therefore less waste. It is a dimension which logically might be expected to indicate something about future dressing percentage.

Miscellaneous Measurements and Dressing Per Cent

Pin-bone width shows a strong positive association with dressing per cent when initial weight is also taken into consideration. This is true whether gain is taken into consideration at the same time or not. With initial weight being taken into consideration, wide pin-bones would mean fatter steers at the beginning of the experiment and this of course would persist in part throughout the experiment.

Pelvis width, pelvis length, hook width, and cannon circumference add but little to the predictive value of the other measurements for dressing per cent. As in the case of gain, cannon circumference is more important than the other three. It should be small.

The few data on knee height, elbow height, and sternum height indicate that a steer should have a comparatively long forearm but be short below the knees to dress high.

Conflict of Ideal Conformations for Large Gains and for High Dressing Percentages

A steer ideal for large gains need not necessarily be ideal for a high dressing per cent. Thus in these data a large paunch girth indicates a steer which will gain rapidly and a small paunch girth indicates a steer which will have a high dressing per cent. A large heart girth is desirable from both standpoints but is not important so far as gain is concerned. The loin should be narrow for high gain but wide for high dressing per cent. The body should be long for gain but short for high dressing per cent. At the withers the steer should be tall for both purposes but height over withers is quite unimportant for dressing per cent. Chest should be shallow in depth for both purposes but is unimportant for gain, etc.

Part of this contradiction in ideals arises from the fact that observed gain includes with it a considerable element of fill. It scarcely seems possible that this can account for all of the contradictions observed. A thin but healthy steer will gain weight more rapidly than a fat steer. The object of steer feeding is not so much to obtain a large increase in weight as it is to improve the weight which is already there and even though he gains more slowly, a moderately fat steer can be brought to the same stage of market desirability with a shorter feeding period and less total expense than a steer that is very thin; but the stin steer would, of course, gain more rapidly. The smaller gain of the former would not make him any less desirable as a feeder steer but would merely mean that he would be fed a shorter time or for a different market. These differences in fatness go far to reconcile the apparent conflict of ideals in width of loin and flank girth. It is not clear that they would explain the conflict of ideals in body length or paunch girth.

Initial Conformation as Related to the Commercial Desirability of the Meat Produced

The Measurements of Commercial Desirability

The primary measure of desirability of the meat was the price per pound appraised for the dressed carcass by men who had had considerable experience in selling meat for the packing companies which killed the steers. These appraisals have been found (7) accurate enough to permit the detection of any large differences in market desirability. The appraisals do not take into account dressing per cent, which has much to do with the price which the butcher could afford to pay for the steers.

To unite in a single term the differences in appraisal and the differences in dressing per cent, the appraised prices were multiplied by the dressing per cent. The product was termed the "meat value per live pound." Differences in yields of fat or hide or other by-products are neglected but such differences would be a minor element in determining the relative value per pound of the live steers to the butcher.

The biometric relations between meat value per live pound and the other variables are multiplicative and not additive. This leads to some discrepancies in the calculations since these were all made according to methods valid where additive relations apply. Moreover, some discrepancies would have crept in through the method of averaging correlation coefficients and the method of correcting for the bias introduced by small numbers. Also there may have been some curvilinearity in the data, correction for which could not be made. Figure 5, patterned after Wright's coefficient method, shows the relations existing between these measures of meat desirability and the other slaughter data and the feedlot weights. Because of the sources of error mentioned the numbers in

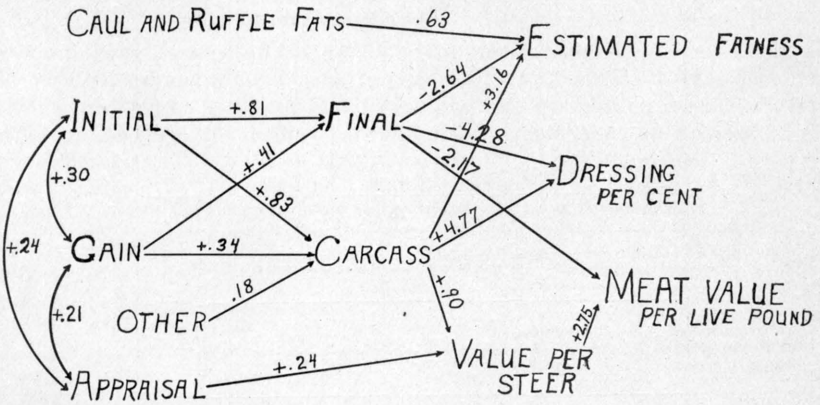

Fig. 5—Path coefficient diagram showing biometric relation between weight, slaughter data, and measures of meat desirability. (The figures shown are all standard regression coefficients except the three primary correlation coefficients between initial, gain and appraisal.)

Figure 5 are only approximations. This is especially true for the standard regression coefficients leading from final and carcass to dependent variables. The very high correlation between final and carcass magnifies the slight errors which arose from the sources mentioned.

The price appraised for the meat is not very closely correlated with any of the other variables shown in Figure 5 except with those determined by it, which include the meat value per steer and the meat value per live pound. Its correlation with final weight is .35; with carcass weight is it .32. With no other measurement or single weight does it have a correlation as high as .29. This of itself makes an unpromising beginning in the search for measurements which at the beginning of the feeding period would be highly correlated with the appraised price of the meat at the end of the feeding period. The multiple correlation between initial weight and gain as independent variables and appraisal as the dependent variable is only .279. The correlation between appraisal and estimated fatness is only .287. The correlations just mentioned and those shown in Table 4 are probably statistically significant if larger than .16 and are certainly significant if larger than .21.

Table 4.—Average correlation coefficients for variables observed on all steers except those born in 1921. (149 degrees of freedom)

Measurement or weight	Cannon circumference	Pelvis length	Width at thurls	Width at hooks	Appraisal of meat	Meat value per steer	Meat value per live lb.	Estimated fatness
Head length	.76	.80	.72	.78	.22	.70	.40	.38
Body length	.78	.78	.82	.80	.19	.75	.32	.42
Chest depth	.75	.82	.75	.83	.13	.71	.29	.36
Width at eyes	.75	.73	.68	.73	.19	.68	.29	.30
Height over withers	.70	.78	.73	.76	.13	.67	.28	.27
Height over hips	.72	.83	.77	.80	.09	.65	.25	.29
Flank girth	.75	.75	.77	.82	.27	.78	.43	.44
Heart girth	.82	.85	.80	.87	.26	.84	.46	.50
Paunch girth	.72	.63	.66	.74	.21	.72	.34	.41
Width at loin	.71	.75	.76	.77	.28	.72	.43	.40
Muzzle circumference	.79	.71	.73	.75	.23	.73	.36	.36
Width of chest	.61	.58	.62	.62	.19	.62	.37	.43
Initial weight	.89	.86	.85	.91	.24	.90	.44	.48
Final weight	.85	.80	.80	.86	.35	.95	.43	.46
Gain	.31	.25	.26	.28	.21	.59	.18	.14
Carcass weight	.84	.82	.80	.86	.32	.97	.54	.58
Dressing per cent	.37	.46	.44	.47	.13	.59	.76	.77
Cannon circumference		.79	.83	.81	.24	.81	.37	.32
Pelvis length			.80	.86	.20	.78	.39	.44
Width at thurls				.84	.17	.77	.37	.37
Width at hooks					.18	.82	.39	.46
Appraisal of meat						.53	.86	.29
Meat value per steer							.69	.59
Meat value per live pound								.76

The first approximation to see whether the various measurements are really helpful in predicting appraisal price or live meat value was obtained by substituting each measurement in turn along with initial weight and gain as the independent variables and either the appraised price or the live meat value as the dependent variable and then noting how much the squared multiple correlation coefficient thus obtained exceeded the similar coefficient obtained when this measurement was not included. Only 5 of the 16 measurements added as much as .01 when appraised price was the dependent variable, the maximum addition being .032 by width at loin. Seven of the 16 added as much as .01 when meat value per pound was the dependent variable, but the maximum addition was only .025 (by depth of chest).

Score Cards for High Appraisal Prices

Even though many of the 16 different measurements seemed likely to be of little value for predicting appraisal prices, yet all 16 were included along with weight and gain in a single multiple correlation coefficient lest some one of them should have an unforeseen importance on account of an

TABLE 5
Score Card for Maximum Appraisal per Pound of Dressed Meat

Measurement or weight desired	Points to be allotted in various combinations: All sixteen measurements, initial weight, and gain	Points to be allotted in various combinations: The five statistically most nearly significant measurements
Large heart girth	13.7	32.4
Shallow chest	11.9	26.8
Wide loin	10.2	17.1
Short height over hips	10.0	15.4
Large flank girth	9.2	8.3
Narrow at thurls	7.1	omitted
Small paunch girth	6.6	omitted
Narrow at hooks	5.5	omitted
Large gains	5.1	omitted
Long head	4.4	omitted
Large cannon circumference	3.7	omitted
Narrow head	3.3	omitted
Tall over withers	3.1	omitted
Large initial weight	2.7	omitted
Large muzzle	1.9	omitted
Narrow chest	.8	omitted
Long pelvis	.6	omitted
Long body	.2	omitted
Multiple correlation coefficient	.492	.409
Portion of variance in appraisal which would remain if all the named variables were perfectly controlled	75.8%	83.2%

intricate balance of relations with the others. The result is shown in Table 5, where the standard regression coefficients are expressed in the familiar form of a score card. Only the first 5 of the regression coefficients seem to be statistically significant. When all other variables are omitted, the multiple correlation coefficient involving these falls from .492 to .409 and these five together afford control over only about one-sixth of the variance in appraisals. This indicates that some of the omitted variables deserve attention in future studies, even though no one of them is likely to be very important.

The things which determine differences in appraisal prices are very largely things not associated with any one of these measurements or with any combination of these measurements. The score cards given in Table 5 are relatively unimportant after all, since rigid selection of steers in accordance with either of these score cards would still leave one with a group of steers only slightly less variable in appraisal prices than the actual unselected group was. The kind of steer described in the score card is large in the fleshy measurements (heart girth, loin, flank girth) but relatively small in most bony measurements (chest depth, hip height, pelvic widths, and paunch girth). This describes a fleshy smooth carcass with the bony protuberances inconspicuous.

Score Cards for Maximum Value per Live Pound

All 16 measurements and initial weight and gain were included in a multiple correlation with value per live pound as the dependent variable. The results are found in Table 6. None of the scores in the first column smaller than 4.0 even approximate statistical significance and those ranging from 4.0 to about 7.0 are of doubtful significance. When those measurements whose net regression coefficients are clearly less than twice as large as their standard deviations are omitted and the multiple correlation coefficient recalculated, the second score card of Table 6 is obtained. Although gain and 9 of the 16 measurements are omitted, the multiple correlation coefficient declines only a little and the degree of control in predicting value per live pound is but slightly less. The regression coefficients involving loin and flank girth in the second score card are of doubtful significance and when those two variables are omitted the third score card is obtained. This shows but little less control over the dependent variable.

The ideal steer for maximum value per live pound corresponds fairly well with the ideal steer for a high appraisal price per pound of dressed meat. This of course is to be expected in view of the high correlation (.86) existing between appraised price and value per live pound. Both score cards agree in calling for a large heart girth, shallow chest, wide loin, large flank girth, and a steer which is not high over the hips. The score card for maximum value per live pound emphasizes large initial weight, narrow head, and small paunch girth, none of which were important in the prediction of appraisal values although so far as they were concerned at all, the ideal was qualitatively the same in both score cards.

Only two-fifths of the total amount of variance is associated with these variables, even when one includes initial weight, gains, and all 16 measurements.

Hence while one would be justified in using this score card in an attempt to secure maximum value per live pound, he would not be justified in placing much reliance in the success of predictions made with it. The score card is erratic and only partially successful for individual steers, although like any other regression equation it might become quite useful when applied to the average measurements of large numbers of steers.

TABLE 6

Score Cards for Maximum Value per Live Pound

Measurement or weight desired	Points to be allotted in various combinations		
	All sixteen measurements, initial weight, and gain	Initial weight and seven most important measurements	Initial weight and the five most important measurements
Large heart girth	14.3	25.3	32.8
Large initial weight	12.9	14.6	22.2
Shallow chest	12.5	16.3	18.1
Short height over hips	10.5	8.8	7.9
Narrow head	7.4	8.1	10.2
Small paunch girth	7.3	11.6	8.8
Long head	6.0	omitted	omitted
Wide loin	5.8	7.2	omitted
Large flank girth	4.8	8.1	omitted
Tall at withers	4.4	omitted	omitted
Short body	2.5	omitted	omitted
Slender cannon bones	2.3	omitted	omitted
Long pelvis	2.3	omitted	omitted
Large gains	1.9	omitted	omitted
Narrow at thurls	1.8	omitted	omitted
Large muzzle	1.6	omitted	omitted
Narrow at hooks	1.2	omitted	omitted
Wide chest	.5	omitted	omitted
Multiple correlation coefficient	.639	.607	.579
Portion of variance in value per live pound which would remain if all the named variables were perfectly controlled	59.1%	63.2%	66.5%

Miscellaneous Measurements and Meat Value

Width at pin bones appears unimportant for any prediction of meat value.

Heights of sternum, elbow, and knee on a score card basis would receive altogether only 15.4% out of a total of 100% divided between them and initial weight, heart girth, and chest depth. None of the four was statistically significant. Elbow height (short) or knee height (tall) may be worth investigation in this connection in the future. Their regression coefficients are about as large as the standard errors. For predicting live meat value much the same thing was found but greatest sternum height (floor of the chest farthest from the ground) seemed to be of some importance.

GENERAL CONSIDERATIONS

It is possible to suppose that there may have been other measurements which if studied would have yielded much higher correlations, but that seems unlikely in view of the variety of measurements actually studied. The measurements included nearly all those which, in the light of previous experience, seemed to the author capable of being taken with much accuracy and which did not almost duplicate each other. Thoroughly tamed and gentle steers have been measured for the width of their thighs or rounds, or for the angle of their rumps, but such measurements did not seem practical on pasture-bred steers as wild as these at the beginning of the feeding period. Perhaps angle of ribs would be worth attention if such a study were repeated.

It is possible to think that there are external characteristics in the steer which are not susceptible of measurement with a tape or measuring rod but which would be recognized by a skilled judge. Such things as pliability of the skin, brightness of the eyes, or apparent gentleness of disposition would fall in this class. The data presented here do not bear directly upon this idea but the study (6) of how closely individual gains and final values of steers could be predicted by men trained in stock judging was undertaken primarily to test this possibility. The success of those predictions was so slight that it seems unlikely that any combination of external traits, no matter what or by whom observed, can be closely enough correlated with subsequent performance of the steers to account for much if any more than half of the variance in the subsequent individual performance of the steers.

All the calculations and discussion concern the performance of individual steers. Even a low correlation for the individual steer may become a high correlation when applied to the average performance of large groups of steers. Any real relation between external conformation and performance, even though the correlation is low, will hold for all the individual steers in the group, whereas the causes of variations from this relation will differ from steer to steer and will tend to cancel each other out and to leave a high correlation between the average measurements and the average performance of large groups of steers divided on the basis of their conformation. This is only another way of saying that something which is true on the overage but very unimportant for the individual, may, because of its average truthfulness, become of considerable importance when applied to large groups of individuals.

The data show a real tendency for large initial weight to be associated with large gains, high dressing percentages, and high final values of the steers. However, when the measurements are also taken into consideration, initial weight of itself becomes much less important. On the whole, the regression coefficients indicate that steers with large fleshy measurements but small bony measurements are those which will have the highest dressing percentages and the most valuable meat at the end of the feeding period.

Large fleshy measurements but small bony measurements indicate a steer which is fatter and more heavily muscled than other steers of the same skeletal dimensions. A steer which has grown more rapidly and become fatter than its lot mates up to the time when the feeding began would be such a steer. It seems to the author an attractive hypothesis that in general whatever internal attributes make a steer thrifty and healthy through his early life continue those effects through the feeding period. Moreover, any differences in tissues present when the feeding began would be largely continued throughout the feeding period.

Mitchell and Grindley (11) studied the correlation between gains made by steers and pigs during the first part of the feeding period and the gains made by these same individual animals during the rest of the feeding period and found generally very low correlations. Hence they concluded there would be little advantage in attempting to allot animals for feeding experiments on the basis of the gains they had already made during a preliminary feeding period. The low correlations they obtained probably were in considerable part the result of differences in fill whereby any animal with more than the average amount of fill when weighed at the end of the initial period would automatically show a large gain for the initial period and a correspondingly small gain for the subsequent period. The reverse would be true for an animal weighed with an abnormally small amount of fill at the end of the preliminary period. The author sees no possibility of repeating this inquiry of their in an experiment planned so as to eliminate these effects of differences in fill. (Correlations between gains in non-consecutive periods would not be as much biased by variations in fill as correlations between gains in consecutive periods.) Studies have been made of milk and butter fat production, of wool production and of egg production, where this problem of fill is not encountered, and in general they have shown correlations of magnitudes ranging from around $+.50$ to $+.80$ for such characteristics. Correlations between the physiological performance of fattening animals at different periods might very well be of somewhat the same magnitude. However, that must remain a matter of opinion unless ways can be devised for studying the performance of fattening animals at different periods, unaffected by differences in fill.

The problem of judging beef steers for future performance seems after all to be quite like the problem of judging dairy cattle for their performance when one is restricted in both cases to the external conformation of the animal as a basis for judgment. In both cases the judgment is worth something and often in actual practical situations it is the only basis available for making a decision which must be made at the time. In the case of the dairy cow a knowledge of the previous performance of the individual makes possible a more accurate estimate of subsequent performance than can be based on external conformation alone. It is not certain whether the same is true in the case of the beef steers.

Possibly one could predict more accurately the future performance of the individual beef steer from a thorough knowledge of the performance of his sire or dam or full sisters or full brothers than from a careful examination of his external conformation alone. That seems, from scattered evidence of various kinds, to be about the case in dairy cattle. Perhaps Record of Performance work for beef cattle could supply the evidence on this point.

Table 7 shows the standard deviations of the variables included in this study. The back-cross lots were more uniform than the others in nearly all respects. The SMS lots were more variable than the others but this is a result of the method of selection and is not any consequence of the

TABLE 7
Average Intra-lot Standard Deviations

Variable	All steers	Herefords	First-crosses	Back-crosses	SMS steers
Observed on all lots:					
Degrees of freedom	216	72	88	30	26
Initial weight	72 lbs.	70 lbs.	71 lbs.	44 lbs.	102 lbs.
Final weight	89 lbs.	85 lbs.	91 lbs.	71 lbs.	110 lbs.
Gain	37 lbs.	37 lbs.	38 lbs.	42 lbs.	27 lbs.
Carcass weight	55 lbs.	54 lbs.	57 lbs.	43 lbs.	66 lbs.
Dressing per cent	1.59%	1.69%	1.57%	1.13%	1.83%
Head length	1.76 cm	1.62 cm	1.85 cm	1.13 cm	2.33 cm
Body length	6.1 cm	6.0 cm	5.8 cm	4.6 cm	8.7 cm
Chest depth	2.43 cm	2.47 cm	2.44 cm	1.39 cm	3.10 cm
Width at eyes	.77 cm	.81 cm	.73 cm	.51 cm	1.00 cm
Height at withers	4.1 cm	4.1 cm	4.3 cm	2.7 cm	4.6 cm
Height over hips	4.6 cm	4.1 cm	5.4 cm	3.1 cm	4.9 cm
Heart girth	6.7 cm	6.3 cm	6.9 cm	3.5 cm	9.4 cm
Paunch girth	9.1 cm	8.9 cm	9.4 cm	5.8 cm	11.5 cm
Flank girth	7.8 cm	7.8 cm	7.4 cm	8.2 cm	9.0 cm
Muzzle circumference	1.51 cm	1.45 cm	1.44 cm	1.31 cm	2.07 cm
Width at loin	1.57 cm	1.59 cm	1.60 cm	1.02 cm	1.94 cm
Width at chest	2.59 cm	2.13 cm	2.78 cm	1.51 cm	3.77 cm
Observed on all but 1921 steers:					
Degrees of freedom	195	69	79	30	26
Cannon circumference	.79 cm	.79 cm	.74 cm	.60 cm	1.09 cm
Length of pelvis	2.00 cm	1.90 cm	1.90 cm	1.40 cm	2.93 cm
Width at thurls	1.79 cm	1.91 cm	1.87 cm	.98 cm	1.99 cm
Width at hooks	2.05 cm	2.00 cm	2.05 cm	1.40 cm	2.70 cm
Appraisal of meat, cents per lb.	.60	.56	.82	.79	.64
Live meat value, cents per lb.	.47	.45	.49	.43	.49
Value per steer, dollars	11.1	9.9	12.3	9.1	11.6
Estimated fatness	2.48%	2.65%	2.42%	2.44%	2.34%
Width at pin bones					
Degrees of freedom	145	42	53	24	26
Standard deviation	1.65 cm	1.70 cm	1.66 cm	.96 cm	2.02 cm
Observed only on 1922, 1928, 1929, and one lot of 1923 steers					
Degrees of freedom	80	30	29	21	-----
Greatest height at sternum	3.06 cm	3.12 cm	3.55 cm	2.09 cm	-----
Least height at sternum	2.53 cm	2.31 cm	3.20 cm	1.63 cm	-----
Height at elbow	2.82 cm	2.86 cm	3.22 cm	2.08 cm	-----
Height at knee	1.66 cm	1.64 cm	1.89 cm	1.32 cm	-----

SMS breeding policy. These SMS steers included some too large and some too small to go in their "standard" classification as well as some which were standard size but off type in color markings. The standard deviations were slightly larger for two-year-olds than for yearlings and larger for yearlings than for calves.

SUMMARY

The correlations between measurements of feeder steers and subsequent gains, dressing percentages, and values of the dressed beef are low but statistically significant.

The most important measurements for high dressing per cent and meat value are a large heart girth in connection with a shallow chest, a wide loin and large flank girth, a large initial weight, small paunch girth, head narrow at the eyes, and short height over hips.

Maximum gains are associated with a long body, tall at the withers, with a large paunch girth but small flank girth and narrow at the loin.

There is a slight but real general tendency for the fleshy but small-boned steer to have a high dressing per cent and more desirable cuts of meat.

Observed gains calculated by subtracting initial from final weights are much affected by differences in "fill" or at least by differences in gains which do not consist of flesh or bone in the parts left in the dressed carcass.

Conformation is often the only basis available for judgment and of course should be given some consideration at all times. However, the data indicate that no score card or standard based on conformation could ever be so accurate that the future performance of individual steers could be predicted from it with but few mistakes. Form and function in these respects are not closely enough correlated.

Steers of many shapes will gain well and steers which gain the same may be of many different shapes. The same is true of dressing per cent and meat values, although future dressing per cent and future live meat value are slightly more closely correlated with conformation than future gain is.

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