TECHNICAL BULLETIN 73

NOVEMBER 1963

Beef Cattle Breeding Research in the Western Region

Agricultural Experiment Station
Oregon State University
Corvallis

Western State Experiment Stations
in cooperation with
The United States Department of
Agriculture

A WESTERN REGIONAL
RESEARCH PUBLICATION

Contents

AUTHORS: R. T. Clark and James S. Brinks, Beef Cattle Breeding Research, 312B New Customhouse Building, Denver, Colorado; Ralph Bogart, Department of Animal Science, Oregon State University, Corvallis, Oregon; Lewis A. Holland, Department of Animal Husbandry, New Mexico State University, University Park, New Mexico; Carl B. Roubicek and O. F. Pahnish, Department of Animal Science, University of Arizona, Tucson, Arizona; James A. Bennett, Department of Animal Husbandry, Utah State University, Logan, Utah; and Ross E. Christian, Department of Animal Husbandry, University of Idaho, Moscow, Idaho.

COOPERATING AGENCIES: The Agricultural Experiment Stations of Arizona, California, Colorado, Hawaii, Idaho, Montana, Nevada, New Mexico, Oregon, Utah, Washington, and Wyoming; the Cooperative State Experiment Station Service, United States Department of Agriculture; and the Agricultural Research Service, United States Department of Agriculture.

Under the procedure of cooperative publications, this regional bulletin becomes, in effect, an identical publication of each of the cooperating agencies, and is mailed under the frank and indicia of each. Supplies of this publication are available at the sources listed above. It is suggested that requests be sent to one source only.

Beef Cattle Breeding Research in the Western Region

R. T. Clark, James S. Brink, Ralph Bogart, Lewis A. Holland, Carl B. Roubicek, O. F. Pahnish, James A. Bennett, and Ross E. Christian

Foreword

The importance of cooperative action in beef cattle improvement investigations has been recognized by research workers in the Western Region for many years. As early as 1924, the Montana Agricultural Experiment Station and the Bureau of Animal Industry, U. S. Department of Agriculture, initiated cooperative research with beef cattle at the U. S. Range Livestock Experiment Station, Miles City, Montana.

Subsequent to the passage of the Research and Marketing Act in 1946, a means was provided for organizing cooperative research on a larger scale. The first regional research project in the nation on beef cattle breeding was approved on July 7, 1947, with all of the western states cooperating in the work described under Western Regional Project W-1.

The objectives of this project were:

(1) To develop inbred lines of beef cattle that will be useful in the improvement of such characters as rate of gain, economy of gain, carcass quality, fertility, and longevity.

(2) To develop effective breeding techniques for improving the productiveness of beef cattle.

(3) To investigate the productiveness of existing lines of beef cattle.

The original project was revised in 1956 and the objectives were restated as follows:

(1) To develop lines of established beef cattle breeds that will be useful in the improvement of economically important characteristics such as weaning weight, rate of gain, economy of gain, carcass composition, fertility, and longevity.

(2) To develop selection criteria and selection and breeding techniques which will be effective in the derivation of productive lines of beef cattle.

(3) To study the inheritance of specific genes and factor interactions.

(4) To determine the genetic causes of decline in vigor, size, fertility, and other characteristics of inbred lines that have been or may be established.

(5) To study the adaptation of lines of beef cattle of known genetic merit to new environments.

(6) To introduce and test new or derived breeds or types of cattle.

W-1 was the first regional project to adapt cattle research information to electronic data processing procedures, and this has speeded up the publication of research results.

The W-1 Committee expresses at this time its sincere appreciation to the Directors of the Agricultural Experiment Stations of the Western Region for their continuing support to this field of agricultural research, and for their help in the development of a sound example of the regional or team approach to research.

Introduction

This bulletin was prepared to provide a useful summary of research on beef cattle breeding in the Western Region for other scientists and the beef cattle industry.

A review of the accomplishments of the Western Region under Project W-1 is presented. It is not a digest of all the work that has been undertaken. It contains the highlights of some of the major contributions that have been reported in technical publications of the cooperating stations. The entire publications list now consists of more than 850 separate papers.

The order of presentation was agreed upon by the several cooperators as being the most logical order for ease of understanding by the reader. Subject matter areas covered are considered in the following sequence: Inbreeding and line development; factors affecting production traits and interrelationships of traits; rate and efficiency of gains; metabolic and physiological studies; type studies, conformation scores, and body measurements; carcass evaluations; performance testing; hereditary abnormalities; and reproductive physiology.

A complete list of the literature cited is included so that the reader may refer to original references and obtain more detailed information.

Inbreeding and Line Development

One of the original objectives of W-1 was the development of inbred lines with production potentials which would be known prior to their possible use in top cross tests or in the crossing of lines. Different rates of inbreeding have been applied to the lines at various stations, with the Colorado station employing some of the most intensive rates. Knapp *et al.* (1951a) outlined the general procedure followed at the U. S. Range Livestock Experiment Station, Miles City, Montana. In all of the lines that have been studied at western stations, selection for performance traits has been emphasized. A number of lines have been discarded where they showed poor comparative performance or, in a few cases, poor combining ability. Within the Western Region there are currently 66 lines of beef cattle of the principal beef breeds. A number of abnormalities have been uncovered within some of the lines. These include dwarfism, hydrocephalus, spastic, cross-eye and double eyelid, depressed temple, double cervix, as well as cancer eye, vaginal prolapse, and heart defects.

Several stations have reported the effects of inbreeding on weaning weights and daily gains. McCleery and Blackwell (1954) reported that calves 25% inbred would be 16 pounds lighter at weaning than noninbreds.

Burgess *et al.* (1954) stated that weaning weight was adversely affected by both the inbreeding of the calf and the inbreeding of the dam, but that the inbreeding of the calf seemed to have the greater effect on weaning weight. The effects of inbreeding were much greater in this study as compared to other studies of a similar nature.

Blackwell *et al.* (1957) found significant negative association of daily gain with inbreeding, but only a slight effect of inbreeding on final weight. He found also that total digestible nutrients per pound of gain increased with inbreeding.

Alexander and Bogart (1959, 1961) reported a depression in gains for four inbred lines during the preweaning period associated with inbreeding of calves. However, no depressing effect due to inbreeding was demonstrated during the weight-constant postweaning test period between 500 and 800 pounds. A possible explanation would be that more highly heritable traits, such as postweaning gain, would not be expected to decline markedly with increased inbreeding, particularly where intense selection is being practiced. Moore *et al.* (1958) stated that daily gain appeared to be only slightly affected by inbreeding.

At the U. S. Range Livestock Experiment Station (unpublished data) where lines were inbred very slowly—approximately 1% per year—and with over 2,000 calf-dam records involved, the following observations have been made:

1. The effects of inbreeding on birth and weaning weights were found to be markedly different for the two sexes.

2. Inbreeding of calf had a more pronounced effect on females than on males. Partial regressions were three times as large for females for birth weight, preweaning gain, and weaning weight. The reason for this marked difference of the effect of inbreeding on performance between the two sexes is not readily apparent. Either a direct influence of genetic material on the sex chromosome itself or a sex influenced condition resulting in differences in hormone production may be involved.

3. Inbreeding of calf and dam had a marked detrimental effect on birth and weaning weights. However, inbreeding of dam had a more detrimental effect on growth of bulls than on heifers. It is possible that bulls, having a higher growth potential, are affected more than heifers by the decreased milk supply of their mothers that is associated with increased inbreeding of dam.

4. Inbreeding of calf had a large detrimental effect on postweaning weights and gains of the selected population of bulls. Similar large detrimental effects of inbreeding were observed for postweaning weights and gains among females.

Stonaker (1962), working with a much smaller population, reported that with respect to weaning weight, heterosis in females was much greater than in males. He compared inbreds to their half-sib linecross contemporaries.

With respect to fertility of bulls as affected by inbreeding, Harris *et al.* (1960) wrote on this subject using semen evaluations as a criterion. They reported highly significant differences in estimated fertility levels in yearling inbred bulls as compared to linecross bulls, and a significantly higher percentage of unsatisfactory bulls within the inbreds. Linecrosses were appreciably superior with respect to semen evaluations as compared to outbred bulls raised in cooperating breeder herds.

In regard to reproduction rates in females, Woodward and Clark (1959) showed an appreciable increase in the number of stillbirths for inbred lines in contrast to outbred groups of cattle. The Colorado station (Stonaker, 1958) found a 12% lower calf crop among inbred two-year-olds as compared to linecrosses, and 10% lower calf crop in inbreds three years old or older compared to linecrosses.

Blood antigen studies by Stroble *et al.* (1954) and by Kushwaha *et al.* (1954) indicated line differences in both occurrence and frequency of occurrence of antigens. In the latter (Colorado) study, the regression of rate of loss of antigens on inbreeding was computed. The slope of the regression was in agreement with that expected, in that increased inbreeding would be expected to decrease the heterozygous class and increase both homozygous classes. These results indicate that the actual effects of inbreeding are closely correlated with the theoretical concepts of homogeneity of inbreds as developed originally by Sewall Wright.

The merits of some of the inbred lines have been tested in cooperative trials with stations and private ranchers. For the most part these trials have consisted of top cross tests where a limited number of inbred bulls were bred to unrelated cow herds, and their progenies compared to outbred stocks have been quite satisfactory from a strictly utilitarian viewpoint. For example, the Montana Experiment Station at its North Montana Branch Station at Havre, reported an average increase of 10% or more in average daily gain of progenies of experiment station sires when compared to progenies of industry sires used in name herds raised in the Havre general area.

In a California trial comparing sires from long selected lines from the Montana and the California stations, the Montana bulls gave a 5 to 8% increase in gain. In both the Montana and California trials, carcass results were quite satisfactory under present market requirements.

Colorado has reported generally favorable responses from cattlemen who have used experiment station inbred bulls in their commercial herds. Steers from such matings have outgained and outgraded steers from Texas, Colorado, and Wyoming with which they were compared. Colorado also has made a number of crosses of inbred lines. These hybrids have excelled in weaning weight, grade, and percent of calf crop.

Hoornbeek *et al.* (1962) tested performance-tested sires from four closed lines of Herefords on commercial cows. This study indicated genetic differences between lines for the production and carcass traits studied. However, no single line excelled in all of the economically important traits. Correlations involving type or condition scores at weaning with performance traits showed that the scores were not indicative of good performance. This emphasizes the desirability of performance testing animals rather than relying on subjective appraisals. There was general agreement between relative performance of the lines and relative performance of the calves sired by bulls from the various lines. Bulls from lines that excelled in a particular trait sired calves in the commercial herd that excelled in this trait.

The Arizona station over a period of three years conducted top cross tests comparing the progeny of sires from several Montana-developed inbred lines with the progeny of sires stemming from private herds (Pahnish *et al.*, 1962). The progeny by sires from one Montana line showed an advantage of 2.5% in weaning weight over the average of the calves by the noninbred sires. Yearling weight advantages of 5.5% and 4.0% (bull and heifer progeny, respectively) in favor of stock sired by inbred bulls of one line were reported. The bull and heifer calves making the greatest postweaning gains were by one of the inbred sires. While this progeny group weighed only about 5.4% more than the herd average at weaning time, gains from weaning to fall yearling age were 15.8% and 6.0% above the herd average for bull and heifer progeny, respectively. There was little practical difference in the grades and condition scores of progenies sired by the inbred and noninbred bulls. It is interesting to note that the experimentally derived stocks did not sire a single dwarf within the randomized cow herd to which they were bred.

From unpublished data taken at the U. S. Range Livestock Experiment Station, Miles City, Montana, on research into the development of lines over a 21-year period, genetic differences are clearly reflected in the ability of calves of different pedigree origin to gain weight from birth to weaning. These results are summarized in Table 1.

Table 1. AVERAGE BIRTH WEIGHT, WEANING WEIGHT, AND BODY SCORES OF CALVES FROM EIGHT INBRED LINES

Line number	Number years	Number calves	Birth weight	180-day weight	Score
			Pounds	*Pounds*	
1	25	2,027	76.8	405	76.8[a]
4	13	332	74.3	371	75.3
5	13	317	73.7	372	75.4
6	11	208	67.0	382	77.5
9	9	257	73.3	397	76.2
10	11	212	78.4	394	75.9
11	8	142	78.8	419	78.8
12	5	97	84.7	431	78.9

[a] Body scores taken over a 21-year period on 1,815 calves.

Table 2. POSTWEANING PERFORMANCE OF HEREFORD INBRED BULLS ON 196-DAY GAIN TESTS

Line number	Years	Number bulls	Initial weight on test	Average daily gain	Weight off test
			Pounds	*Pounds*	*Pounds*
1	1955–62	255	456	2.44	934
4	1955–62	50	419	2.42	893
6	1955–62	46	406	2.22	841
9	1955–62	40	445	2.21	879
10	1955–62	49	417	2.37	881
11	1955–62	43	464	2.45	944
12	1957–62	36	471	2.53	966

With reference to gains on test, these data also reveal wide differences in postweaning gaining ability of bulls from the several lines (Table 2).

Tests through crossline matings are being made at the Miles City station. Preliminary results show that crossline bull calves are 19 pounds heavier at weaning than the straight-line bull calves. Crossline heifer calves are 29 pounds heavier at weaning than the straight-line heifer calves. These results are equivalent to an increase of 4.68% for the crossline bulls and an increase of 7.82% for the crossline heifers.

As the result of preliminary experiments in crossbreeding involving Charolais X Hereford, the Miles City station initiated a project in 1961 involving all possible crosses of Charolais X Hereford, Charolais X Angus, and Hereford X Angus compared to straight-breds of these three breeds.

The original trials showed that Charolais X Hereford crosses were 62 pounds heavier at weaning than the straight Herefords and gained 0.30 pound more per day in the feedlot than the straight Herefords. The carcass grades of the straight Herefords were Low Choice, whereas the Charolais X Hereford crossbreds graded High Good. Tenderness tests showed that the straight Herefords were slightly more tender than the Charolais X Hereford crossbreds. Based on physical separation of the 9-10-11 rib cut, the Hereford steers had the smallest amount of lean and the largest amount of total edible fat.

California unpublished data on crossbreeding British breeds, Angus and Hereford, indicate that considerable savings in feed can be realized since crossbreds reach desired carcass weights earlier than straight-bred cattle.

Factors Affecting Production Traits and Their Interrelationships

The determination of the relative influence of genetic and environmental factors on production traits of beef cattle has been pursued at several stations. Estimates of heritability and differences between performance of lines have been calculated to assess the influence of genetic factors. The influence of environmental factors, including year differences, age of calf, age of dam, and sex of calf, have been found to affect some traits markedly, necessitating adjustment for these effects when selecting breeding animals to maximize genetic improvement.

Interest in the interrelationship of traits is, of course, due to the fact that not one but many traits of beef cattle are of economic importance. It is recognized that the number of traits for which selection is practiced should be limited to the greatest possible extent. Nevertheless, the minimum number of traits for which selection is necessary are growth, efficient feed conversion, milking ability, soundness, fertility, and the characteristics which contribute to desirable meat quality. Therefore, it is necessary to determine how selection for any one of these traits will affect the others—positively or negatively.

A brief discussion of factors affecting production traits and the interrelationships of traits which have received attention in the Western Region is presented. Table 3 gives heritability estimates of production traits.

Birth weight

Prenatal growth is generally related to postnatal growth, but not to such traits as efficiency of feed conversion or subsequent grade. There is apparently a slight relationship of prenatal growth with lean, but none with yield of cuts, carcass grade, or tenderness. There are apparently no negative associations of birth weight with other economically important traits. Woodward and Rice (1958) found a positive relation between birth weight and body length within given weights.

More mature cows give birth to larger calves than younger, less mature cows (Sawyer *et al.,* 1949; Koch and Clark, 1955a). Also, larger cows have larger calves than smaller cows of comparable ages. In a series of papers, Koch and Clark (1955 a, b, c, d) emphasize the importance of maternal effects on birth weight. Male calves are larger at birth than females (Koch and Clark, 1955a).

Table 3. Heritability Estimates for Production Traits

Trait	Heritability	Reference
Birth weight	0.23, 0.42, 0.34	Knapp and Nordskog, 1946a
	.53	Knapp and Clark, 1950
	.35	Koch and Clark, 1955b
	.44, .35	Koch and Clark, 1955c
	.42	Koch and Clark, 1955d
	.72	Shelby *et al.*, 1955
	.62	Shelby *et al.*, 1963
Weaning weight	.12, 0, .30	Knapp and Nordskog, 1946a
	.28	Knapp and Clark, 1950
	–.06	Romo and Blackwell, 1954
	.24	Koch and Clark, 1955b
	.11, .25	Koch and Clark, 1955c
	.19	Koch and Clark, 1955d
	.30	Rollins and Wagnon, 1955
	.23	Shelby *et al.*, 1955
	.30	Rollins and Wagnon, 1956a
	.81	Lindholm and Stonaker, 1957
	.42, .57	Wagnon and Rollins, 1959
	.28 (bulls)	Pahnish *et al.*, 1961c
	.57 (heifers)	Pahnish *et al.*, 1961c
	.08 (steers)	Blackwell *et al.*, 1962
	.31 (heifers)	Blackwell *et al.*, 1962
	.24	Shelby *et al.*, 1963
Gain—birth to weaning	.21	Koch and Clark, 1955b
	.07, .17	Koch and Clark, 1955c
	.12	Koch and Clark, 1955d
Gain in feedlot	.99, .46, .97	Knapp and Nordskog, 1946a
	.10 (1st 84 days)	Knapp and Clark, 1947
	.54 (2nd 84 days)	Knapp and Clark, 1947
	.84 (3rd 84 days)	Knapp and Clark, 1947
	.72 (252-day period)	Knapp and Clark, 1947
	.65, .77	Knapp and Clark, 1950
	.70	Knapp and Clark, 1951
	.60	Shelby *et al.*, 1955
	.57	Lickley *et al.*, 1960
	.46	Shelby *et al.*, 1960
	.76	Blackwell *et al.*, 1962
	.40	Brinks *et al.*, 1962b
	.48	Shelby *et al.*, 1963
Days on feed to reach a given grade	.92	Lindholm and Stonaker, 1957
Yearling weight	.37	Romo and Blackwell, 1954
	.47	Koch and Clark, 1955b
	.43	Koch and Clark, 1955c
	.48, –.35	Wagnon and Rollins, 1957
	.44, –.19	Wagnon and Rollins, 1959
	.36	Marchello *et al.*, 1960
	.10 (steers)	Blackwell *et al.*, 1962
	.71 (heifers)	Blackwell *et al.*, 1962

Table 3. Heritability Estimates for Production Traits (Continued)

Trait	Heritability	Reference
Gain from weaning to yearling	0.39	Koch and Clark, 1955b
	.18	Koch and Clark, 1955c
	.27, .03	Wagnon and Rollins, 1959
	.32	Blackwell *et al.*, 1962
Yearling gain	.24	Romo and Blackwell, 1954
	.40	Koch and Clark, 1955d
Final feedlot weight	.81, .69, .94	Knapp and Nordskog, 1946a
	.86, .92	Knapp and Clark, 1950
	.84	Shelby *et al.*, 1955
	.77, .55	Shelby *et al.*, 1960
	.70	Blackwell *et al.*, 1962
	.48	Brinks *et al.*, 1962b
	.64	Shelby *et al.*, 1963
Slaughter weight	.70	Shelby *et al.*, 1963
Mature weight of cow	.72	Lickley, *et al.*, 1960
	.75, .57, .73, .62	Brinks *et al.*, 1962a
Efficiency of gain	.75, .54, .48	Knapp and Nordskog, 1946a
	.22	Shelby *et al.*, 1955
	.27, .36	Lickley *et al.*, 1960
	.32	Shelby *et al.*, 1960
Weaning score	.53, 0	Knapp and Nordskog, 1946b
	.28	Knapp and Clark, 1950
	.31	Knapp and Clark, 1951
	.50, .30 (total score)	Koger and Knox, 1952
	.46, .13 (lowness score)	Koger and Knox, 1952
	.15, .10 (thickness score)	Koger and Knox, 1952
	.15, .18 (smoothness score)	Koger and Knox, 1952
	.24, .23 (weaning grade)	Koger and Knox, 1952
	.26	Romo and Blackwell, 1954
	.18	Koch and Clark, 1955b
	.16, .15	Koch and Clark, 1955c
	.16	Koch and Clark, 1955d
	.42, .29, .36	Rollins and Wagnon, 1956b
	.38 (steers)	Blackwell *et al.*, 1962
	.26 (heifers)	Blackwell *et al.*, 1962
	.23	Shelby *et al.*, 1963
Yearling grade	.63	Romo and Blackwell, 1954
	.27	Koch and Clark, 1955b
	.14	Koch and Clark, 1955c
	.27	Koch and Clark, 1955d
	.40 (steers)	Blackwell *et al.*, 1962
	.34 (heifers)	Blackwell *et al.*, 1962

Growth from birth to weaning

Gains of calves during the suckling period, or weaning weights adjusted to a constant-age basis, are larger from more mature cows than from younger, less mature cows and, also, larger cows wean heavier calves than smaller cows of comparable ages (Sawyer *et al.*, 1948; Rollins and Guilbert, 1954; Koch and Clark, 1955a; Nelms and Bogart, 1956; Blackwell *et al.*, 1958; Pahnish *et al.*, 1958b). Bull calves are heavier at weaning than heifers or steers, and steers are heavier than heifers where feed conditions are adequate for sex differences to be expressed (Rollins and Guilbert, 1954; Pahnish *et al.*, 1958b, 1961a, c), while under more adverse conditions little difference between weaning weights of steers and heifers is present (Sawyer *et al.*, 1948). Pahnish *et al.* (1958a) found that factors for adjusting calves to a constant weaning age of 270 days were considerably higher for bull calves than for heifer calves.

Weaning weights or gains during the suckling period are not highly heritable (Table 3). Repeatability estimates of weaning weights are higher than heritability estimates (Rollins and Wagnon, 1956a).

Heavier calves at birth, calves born within a season of the year that permits the nursing cow to be under better pasture conditions, and those reared during more favorable years gain more during the nursing period and reach heavier weaning weights (Rollins and Guilbert, 1954; Koch and Clark, 1955b; Bogart *et al.*, 1956; Nelms and Bogart, 1956; Clark *et al.*, 1958).

Lindholm and Stonaker (1956, 1957) consider weaning weight of the calf as one of the most important traits influencing net income to the rancher. Consequently, it is an important trait to include in a selection index. However, because of the negative genetic correlation of milking ability with postweaning growth (Koch and Clark, 1955d), selection for weaning weight alone would be less desirable than combining selection for both preweaning and postweaning rates of gain.

It appears evident, also, (Rollins and Wagnon, 1955) that selection for increasing weaning weights would be much more effective under optimum conditions than under suboptimum conditions, particularly if the latter were quite adverse.

Rollins *et al.* (1952) concluded that the growth mechanism and genetic factors from birth to four months of age are different from and independent of the mechanism and genetic factors operating for the period from four months to weaning age.

Postweaning growth

Gains made in the feedlot, or slaughter weights adjusted to a common-age basis, are highly heritable (Table 3). Values ranging from 0.24 to above 0.80 have been obtained for estimates of heritability (Knapp and Clark, 1950; Romo and Blackwell, 1954; Willson *et al.*, 1954; Hitchcock *et al.*, 1955; Koch and Clark, 1955b; Willson and Flower, 1956; Shelby *et al.*, 1957; Lickley *et al.*, 1960).

Bulls gain more rapidly than steers and steers gain more rapidly than heifers (Bogart and Blackwell, 1950; Dahmen and Bogart, 1952). Mason *et al.* (1958a) have shown that males vary more than females in rate of gain.

Many studies have been made on factors that influence postweaning rate of gain. Larger calves at birth generally gain more rapidly than smaller ones (Woodward *et al.*, 1954a, b; Woodward and Rice, 1958). However, gains during the suckling period, or weaning weights, are not so consistently related to postweaning gains (Sabin *et al.*, 1958). Apparently, two conflicting forces are operating which influence postweaning gains. Calves that do not have a sufficient supply of milk during the nursing period, and consequently have lower suckling gains, will tend to compensate during the postweaning period by making more rapid gains (Koger and Knox, 1951; deBaca *et al.*, 1959). On the other hand, inheritance of rapid growth would tend to be expressed both prior to and following weaning. One of these influences would tend to create a negative relation between preweaning and postweaning gains, while the other would create a positive relation (Knapp and Clark, 1951; Dahmen and Bogart, 1952; Pierce *et al.*, 1954; Willson *et al.*, 1954; Woodward *et al.*, 1954b; Blackwell *et al.*, 1958). Thus, weight for age at the time calves are put on test, or age when calves are put on test at a constant weight, may or may not be related to test gains, depending upon the relative influence of preweaning genetic and environmental influences. Cobb *et al.* (1961) found positive relationships among weights of cattle at various ages, although there were negative relations between suckling and postweaning rates of gain. Blackwell *et al.* (1958) found that the relation of age of dam to postweaning gains is opposite to the relation between age of dam and preweaning gains. Younger and very old cows wean lighter calves than cows in the age range in which they are at the peak of their productive life, but these smaller calves at weaning from the younger and older cows gain more rapidly following weaning. Castle *et al.* (1961) found that although calves compensate in gains made on the range for lower rates of winter feeding, an optimum rate of winter feeding to allow gains of 1.6 to 1.8 pounds per day results in greatest production at the lowest cost under eastern Oregon conditions.

Koch and Clark (1955d) stated that selecting for gains to weaning will increase genic value for growth response, and to a slight extent increase genic value for maternal environment. This may be partly nullified by the negative genetic correlation between maternal environment and postweaning growth response. Selecting cows on the basis of weaning weight of their calves may increase genic value for milking ability but decrease genic value for growth. Selection for gains from weaning to slaughter may increase genic value for growth but decrease genic value for milking ability.

Scores for type and conformation and body measurements show little relationship to rate of gain during either the preweaning or postweaning periods (Knox and Koger, 1946; Knapp and Clark, 1951; Knox *et al.,* 1951; Durham and Knox, 1953; Woodward *et al.,* 1954a, b; Bogart *et al.,* 1955, 1956; Koch and Clark, 1955b; MacDonald and Bogart, 1955; Knox, 1957). Hoornbeek *et al.* (1962) found a negative association between scores for conformation or condition at weaning and subsequent performance of steers in the feedlot. Romo and Blackwell (1954) found negative genetic relationships between grade at weaning or at yearling age and weight at different times or gains from weaning to yearling age. It appears that conformation may have little association with gains, but that animals of smaller type tend to grow less rapidly and fatten at lighter weights. Thus, a negative relation between grade and rate of gains could exist. Unfortunately, scores on conformation frequently are influenced by degree of fatness, and the meaning of results when scores are related to gains may not be clear.

There is some evidence from the Oregon data that longer-bodied animals gain more rapidly than those that are larger in heart girth and shorter in body. Alexander and Bogart (1959, 1961) did not find a depressing effect of inbreeding on rate of gain. Blackwell *et al.* (1962) found that individual differences in growth and body size are highly heritable when cattle are under uniform conditions. Genetic correlations were generally high among traits involving size and growth rate.

Feed efficiency

Brinks *et al.* (1962a) found that mature body size of cows is highly heritable and that larger cows tend to produce calves that gain more rapidly throughout the growing period. Feed efficiency is closely related to rate of postweaning gain, and the factors that are related to rate of gain are generally also related to feed efficiency (Dahmen and Bogart, 1952; Pierce *et al.,* 1954; Woodward *et al.,* 1954b; Lickley *et al.,* 1960). Bulls are more efficient in converting feed into gains than heifers (Nelms and Bogart, 1955) even though they eat no more per unit of body weight (Ampy and Bogart, 1962). Heavier calves at birth are more efficient than lighter calves at birth, and younger calves of the same weight are more efficient than older ones. Much of the variation in feed efficiency determined on a weight-to-weight feed test can be accounted for by variations in birth weight, rate of gain during the feed test, and weight for age at the time the feed test starts. (Nelms and Bogart, 1955; Pierce *et al.*, 1954.)

Blackwell and Hurt (1956) found no relationship of intensity of red color in Hereford cattle with range performance, feedlot performance, or carcass merit.

The research that has been done on interrelationship of traits has been most fruitful in the Western Region. It points clearly to the necessity for considering carefully all economically important traits in a selection program, because selection for only one trait might lead to improvement or to degeneration of another. Implications of these studies point to the necessity of selecting on the basis of an index in which each trait is properly weighted so that over-all improvement of beef cattle can be accomplished.

Excellent summaries on interrelationship of traits and factors influencing production traits have been published. Effects of climatic environment on range cattle production (Roubicek *et al.*, 1957c), prenatal development (Roubicek *et al.*, 1956d), birth to weaning (Roubicek *et al.*, 1956e), postweaning performance (Roubicek *et al.*, 1956b), maternal factors (Roubicek *et al.*, 1957a), carcass and meat studies (Roubicek *et al.*, 1956a), reproduction (Roubicek *et al.*, 1956c), and genetics of cattle (Roubicek *et al.*, 1957b) are excellent summaries.

Rate and Efficiency of Gains

Some of the early work on rate and efficiency of gains was done at the U. S. Range Livestock Experiment Station. Quesenberry (1950) summarized production records for the steer progeny of 13 sires which demonstrated marked sire differences in weaning weights (392 to 493 pounds), daily feedlot gains (1.89 to 2.34 pounds), and final weights (868 to 1,079 pounds at 14 to 16 months of age). Knapp and Clark (1950) presented estimates of heritability based on a large number of sires (Table 3). The relationship between a sire's weight at 15 months of age and weight of his offspring, when a large number of sires were studied, was linear. Five bulls that had been progeny tested by mating them to randomly selected cows showed remarkably close agreement in performance (rate of gain) of their offspring in the test and when used on the line herd cows.

Woodward and Clark (1950) presented data on 11 bulls that were used at both Miles City and Havre. Average rate of gain of steer progeny varied from 1.68 to 2.28 pounds per day at Miles City and 1.59 to 2.30 pounds per day at Havre. There was a sire X station interaction because gains of the sire group were not in the same order at the two stations. TDN per 100 pounds of gain varied for the sire groups from 495 to 564 pounds at Miles City and from 461 to 595 pounds at Havre. Again, there was a sire X station interaction. Because of the sire X station interaction in rate and efficiency of gains, these investigators stress the importance of standardized and refined procedures if comparative sire ratings are to be made in a breed improvement program.

Knapp *et al.* (1951b) have shown that great improvement can be made by selecting for rate of gain. During a period of 15 years, a conservative estimate is an improvement in daily gain of 0.16 pounds and an improvement in weight at 15 months of age of 66 pounds. Haaby *et al.* (1955) presented data on seven individually fed bulls which showed great variation in animals of the same line of breeding. The animals ranged from 305 to 375 pounds gain in 150 days, and TDN required per 100 pounds of gain ranged from 376 to 469 pounds.

Quesenberry (1957) presented data on seven sire groups of steers in which weaning weights ranged from 398 to 448 pounds at 180 days of age. Daily gain in the feedlot ranged from 2.06 to 2.62 pounds per day, and final feedlot weights ranged from 916 to 1,072 pounds at 14 to 16 months of age. Hybrid vigor from crossing inbred lines varied from none to an increase of 20%. The use of inbred bulls from the Miles City station on unrelated outbred cows produced faster-gaining steers than randomly selected bulls on similar cows.

Wagnon and Rollins (1957, 1959) estimated heritability of long yearling weights of heifers at 0.48 in a herd managed under good nutritional levels, but obtained a negative heritability in a herd managed under austere conditions. Rollins *et al.* (1962) presented data suggesting that bulls can be effectively selected on the basis of weight-for-age following a postweaning test period of four months on a roughage ration. They found a relationship between rate and efficiency of gains, and they also observed that weight-for-age was preferable to feed test gain as a criterion for improvement.

Guilbert and Gregory (1952) presented data on body weight and body measurement growth of cattle that were taken over a period of 25 years. Weights of heifers at 12 months of age by sire groups varied from 597 to 730 pounds when offspring from 7 sires were compared. Skeletal maturity was reached at an earlier age than maturity of muscle or fat tissue. Heifers reached 50% mature size at 12 months of age, while bulls were 15 months old before 50% mature weight was reached. Moore *et al.* (1961) computed constants for the effects of certain environmental and genetic factors affecting rate of gain of bulls on performance test. They found that daily gain was significantly affected by year, line of sire, initial age, and initial weight.

Kidwell *et al.* (1952), from allometric growth studies, concluded that changes in linear skeletal dimensions could be made by selection with fewer difficulties than changes in muscular or fatty tissue. Bogart and Blackwell (1950) compared top-performing bulls with lower-performing bulls. They reported the top half as gaining 2.62 pounds per day on 6.41 pounds feed per pound of gain, while the lower half gained 2.32 pounds per day and required 7.46 pounds feed per pound of gain. Also, a comparison in rate and efficiency of gains was made of heifers and bulls. Bulls gained 1.34 times as rapidly and required 0.75 the feed per unit of gain as heifers.

Several studies have been made in which breeds have been crossed. In many of these studies the use of Brahman breeding in the crosses has been employed. Hubbert *et al.* (1955) compared Herefords with Hereford X Brahman crossbreds in eastern Oregon and found that the Herefords made more rapid gains in the feedlot but did not equal the crossbreds in rate of gain on the summer range. Final weights were slightly in favor of the crossbreds. Rollins and Ittner (1956) compared Herefords with Brafords ($\frac{3}{4}$ Hereford and $\frac{1}{4}$ Brahman) and found that the crossbreds gained more rapidly during the summer when temperatures were high and reached greater final weights than the Herefords. Efficiency was in favor of the Herefords. Differences between the groups were not large. Carroll *et al.* (1955) compared Herefords with Brahman X Hereford crossbreds and found that Herefords gained more in the feedlot (2.16 compared with 1.90 pounds per day) and required less feed per 100 pounds of gain (843 compared with 929 pounds) even though initial weights of the two groups were practically identical.

Knapp *et al* (1949) and Quesenberry (1950, 1957) compared Herefords with first-generation crossbreds (Shorthorn bull X Hereford cows), second-generation crossbreds (Angus bull X first-generation crossbred cows), and third-generation crossbreds (Hereford bull X second-generation crossbred cows). All crossbred steers gained more rapidly than the Herefords during both suckling and feedlot periods, but feed efficiency was not markedly different for the different breeding groups. Growth rate of the females was greatest for the second-generation females up to 18 months of age, but first-generation females reached the largest mature size. Growth up to weaning increased with increases in crossbreeding generations. This may reflect heterotic effects on milking ability of crossbred dams rather than growth potential of the calves. The fact that first-cross heifers were the largest at maturity but not at 18 months of age would indicate that they had great growth potential but did not enjoy a maternal environment which would permit full expression of their growth potential up to weaning.

Koger (1948) divided young cows into five groups on the basis of weaning weights of their calves, after which he studied subsequent calf production of these cows. He found a high repeatability of weaning weight.

Stonaker (1951) described a herd of cattle in which inbreeding averaged about 31% and which had been closed to outside breeding for 25 years. He pointed out that cattle in this herd were intermediate in size and showed considerable uniformity. Apparently, inbreeding to this extent did not decrease size, although it is unknown whether it may have delayed growth rate.

Koger and Knox (1951), Urick *et al.* (1957), and Kidwell (1954) showed that growth of calves has the same linear expression during different periods when the environment is constant, but with fluctuations of stress conditions, growth during one phase may be negatively related to growth during others. Cumulative growth curves for compact and large-type cattle showed linear growth up to weaning, from weaning until they were put on feed, and during the feedlot phase of production. However, the slope of the growth curve was different when each of these phases was compared with the other two. The large-type cattle grew more rapidly than the compact-type cattle in all phases.

Bailey and Gilbert (1962) analysed data on lines selected for rate of gain or economy of gains under range conditions and lines selected for rate of gain, economy of gains, or conformation under irrigated pasture conditions. There were significant line differences in rate and efficiency of gains in cattle under the more favorable environment. Calves in the line selected for conformation gained less rapidly and efficiently, whereas those selected for rate of gain and economy of gains were about equal.

Metabolic and Physiological Studies

Physiological approaches have been designed to gather basic information on the inheritance of physiological traits. Knowledge of this nature has value in understanding the metabolic pathways concerned with physiological traits, in estimating the possibility of concommitant selection against deleterious factors, and in either increasing our accuracy in selection for productive traits or making it possible to select for certain traits at earlier ages.

A great deal of study is needed in a field such as this because so little previous work has been done. Two major problems in physiological studies are: (1) The development of methods to use, and (2) the establishment of normal values and the amount and causes of variation. However, such information is essential before any studies can be made in which physiological findings can be used to explain variations in production traits or to study the relationship between physiological characteristics and production traits with the hope of finding physiological measurements that can aid us in our selections.

Metabolites in the blood and urine in relation to production traits

Normal values have been established for blood levels of urea nitrogen, amino acid nitrogen, creatinine, uric acid, and creatine; and for urine levels of total nitrogen excreted per day and per unit of weight per day, urea nitrogen, ammonia nitrogen, creatinine, uric acid, and the ratio of urea to ammonia nitrogen (MacDonald *et al.*, 1953, 1956; Krueger *et al.*, 1956). These levels were determined at birth and at each 100 pounds increment in body weight up to 800 pounds. Calves on feed test show less variation from time to time and from animal to animal than while they are running with their dams on pasture and are subjected to more environmental variations.

Rapidly and economically gaining calves have lower levels of blood amino acid and urea nitrogen, and excrete less urea through the urine (Price *et al.*, 1956). Apparently, the rapidly gaining animals have the ability to draw amino acids from the blood stream and build them into muscle growth. The ones that pull less of the amino acids from the blood stream are confronted with deamination of the amino acids and the excretion of the nitrogen fraction with the carbonaceous fraction being used for the storage of fat. All animals tend to make a shift to less use of the amino acids, less muscle growth, more excretion of nitrogen, and greater deposition of fat with increasing size. The more rapidly and economically gaining animal has a metabolism approaching that of a younger animal, while the poor-doing animal more nearly resembles a mature one. Sex differences appear in the same direction as shifts with maturity, with bulls showing a metabolism that is more like the younger animals and heifers showing a metabolism more like the mature animals (Ampy and Bogart, 1962).

Breed and line differences and sex differences in the blood and urine constituents studied followed approximately the same patterns as those of rate and efficiency of gains.

An apparatus was developed for collecting urine from bulls or heifers (Mason *et al.,* 1956c).

Hematological studies

Normal values that have been established are: hemoglobin 12.4 g. per 100 ml. for heifers and 11.8 g. per 100 ml. for bulls at 500 pounds body weight and 13.3 and 13.1 g. per 100 ml. for females and males at 800 pounds body weight (Price *et al.,* 1957, 1959; Alexander *et al.,* 1959). The levels at 500 and 800 pounds were positively correlated. Herefords generally were lower in hemoglobin than Angus. Calves with lower hemoglobin levels made more rapid and efficient gains.

Hematocrit percentages averaged 40.8 for heifers and 39.7 for bulls at 500 pounds body weight, and 44.5 and 43.4 for heifers and bulls, respectively, at 800 pounds. There were some line differences in hematocrit percentages, but no sex differences, and very little relationship of the levels at 500 and 800 pounds body weight.

Red cell counts per cubic mm. of blood were higher (8.25 million) at 800 pounds than at 500 pounds body weight (7.70 million), but there were no line or sex differences. The counts at the two weights were correlated. Calves with lower red cell counts made more rapid gains.

The average corpuscular volume was 53.2 cubic microns. The single corpuscular hemoglobin content was 16 micromicrograms and the corpuscular concentration was 30.3%. There were no sex or line differences, and these traits were not associated with performance traits.

White cell counts (total) and lymphocytes were higher at 500 than at 800 pounds body weight. There were sex, breed, and line differences in total white cell counts, and some differences in lymphocyte counts were attributable to sex. Higher lymphocyte counts were associated with more rapid and economical gains.

The amount of hemoglobin per unit volume of the blood, hemoglobin content of individual red blood cells, and the concentration of hemoglobin in each red blood cell increased in beef calves (Hereford and Angus) with increases in body weight from 500 to 800 pounds. The number of red blood cells decreased with increased body weight. The number of white blood cells, lymphocytes, and monocytes decreased with increases in body weight, while the numbers of neutrophils, eosinophils, and basophils were variable from weight to weight (Bhannasiri *et al.,* 1961).

Cornelius *et al.* (1956) have shown that short-headed dwarf cattle up to 14 months of age are normal in red cell counts and all differential white cell counts except for lymphocytes and neutrophils.

They were low in lymphocyte count (55.6 compared with 68.2 for normal calves) and high in neutrophils (33.3 compared with 23 for normal calves). Hafez *et al.* (1958a) found that dwarfs are lower in hemoglobin, hematocrit, and white cell count than normal calves.

Blood protein fractionation

Normal values have been established at 500 and at 800 pounds body weight for percentages of albumen, alpha globulin, beta globulin, and gamma globulin, and for the ratio of albumen to globulin (Price *et al.*, 1959).

The percentages of these protein fractions were about the same at 500 and at 800 pounds body weight, and there appeared to be no line, breed, or sex effects influencing these protein fractions. The percentage of gamma globulin was positively related to rate of gain (Ampy *et al.*, 1961).

Cornelius *et al.* (1956) have shown that short-headed dwarfs are normal in albumen and alpha, beta, and gamma globulin fractions, as well as in total proteins of the blood.

Pahnish *et al.* (1961b) found that heifers varied more in albumen and alpha, beta, and gamma globulins than bulls. There were significant effects of sires on the beta globulin fraction.

Endocrine studies

Since it is known that hormone balance influences the nature and amount of growth, research workers in seeking an explanation as to how inheritance brings about growth differences have been led to explore the endocrine relationships of animals differing in their inherent capacity to grow. Three approaches have been used: (1) Determination of hormone content of glands and tissues from cattle that vary in growth rate; (2) determination of endocrine function in the live animal by isotope studies; and (3) the response of animals to injected hormones.

Thyrotropic and gonadotropic hormone contents of pituitaries from beef cattle have shown that the more rapidly gaining animals have a higher content of thyrotropic hormone in their pituitaries than the less rapidly gaining animals (Burris and Bogart, 1953; Burris *et al.*, 1953a, b, 1954; Krueger *et al.*, 1954). Beef cattle fed rations very low in protein (potatoes and straw) for 125 days had the same amount of thyrotropic hormone in their pituitaries as was present in pituitaries from animals on a normal ration (Nicholson *et al.*, 1962).

Lucas *et al.* (1950) found that small-type steers had smaller endocrine gland weights than large-type cattle. Thyroid and adrenal weights were correlated with rate of gain.

The hormone content of pituitaries from dwarf animals has been compared with those from normal animals. Carroll *et al.* (1951) presented data that indicate a deficiency of thyrotropic hormone in the pituitaries of dwarf calves, while the pituitaries from dwarfs contained normal amounts of growth hormone and gonadotropic hormone. They postulate that the deficiency in thyrotropin might account in part for the slower growth of dwarfs. However, Cornelius *et al.* (1956) found that protein-bound iodine levels of dwarfs were normal, and they concluded that the short-headed dwarf is not a primary thyroid cretin.

Galgan *et al.* (1956a, b) reported preliminary results in which a higher rate of gain was associated with lower effective half-life of radioiodine and a greater urinary excretion of radioiodine. Slower gains were associated with higher thyroid uptake of iodine. Ham *et al.* (1954) were unable to find a significant relationship of protein-bound iodine with rate or efficiency of gains.

Bulls gain more rapidly and efficiently than heifers (Bogart and Blackwell, 1950; Dahmen and Bogart, 1952). Investigations have been made on the influence of injected testosterone into heifers and steers on rate and efficiency of gains (Bogart *et al.*, 1951; Burris *et al.*, 1952, 1953b, 1954). Testosterone was injected at a rate calculated from normal excretion in the human to be in the physiologically normal range of production of testosterone in bulls. This amount was 1 mg/kg body weight per week, and it was given as micropellets intramuscularly. Testosterone injections (Figure 1) resulted in an increased daily rate of gain of 0.1 pound in steers and 0.5 pound in heifers, and a decreased feed requirement per 100 pounds of gain in steers of 41 pounds and in heifers of 180 pounds, with no change in daily feed intake. There was marked masculinization, but palatability scores, tenderness, evaporation loss, and drip loss of the meat were not altered by testosterone administration. Testosterone caused a marked increase in protein and a decrease in the fat content of the carcass. This was particularly noticeable in heifers. As a result of the alteration in ratio of fat and lean, carcass grades were lowered by testosterone administration.

Testosterone administration also altered the hormone content and size of certain endocrine glands (Burris and Bogart, 1953; Burris *et al.*, 1953a). The gonadotropic content of the pituitary glands was decreased by testosterone, while the thyrotropic content of the pituitaries was markedly increased. Assays for these pituitary hormones were made by use of male chicks. The thyroid glands of cattle receiving testosterone were larger than those of normal comparable cattle. To assay these thyroid glands for thyroxine content required the development of an assay method. Mice were made hypo-

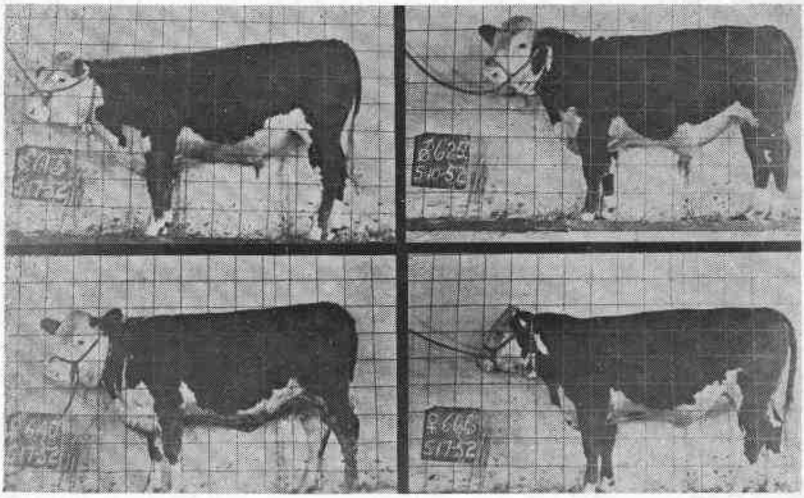

Figure 1. Testosterone injections caused increases in rate of gain and feed efficiency but also resulted in masculinization as shown in calves on the right. (Courtesy of Oregon State University.)

thyroid by giving them thiouracil in the drinking water, after which graded doses of mascerated thyroid gland tissue were injected. This addition of thyroxine from the administered thryoid gland material increased the metabolic rate of the mice. To determine metabolic rates of the mice, they were asphyxiated in half-pint sealed fruit jars. The time required for asphyxiation was the inverse of the metabolic rate.

Thyroids from testosterone-treated animals contained less thyroxine than thyroids from normal cattle. This was considered to be an indication of greater thyroxine release of these animals.

Testosterone-treated heifers generally did not ovulate, as evidenced by lack of corpora lutea at time of slaughter (Burris *et al.*, 1954; Krueger and Bogart, 1959). Of 24 heifers treated with testosterone, only 4 had ovulated at a weight of 800 pounds, whereas all 24 control heifers had ovulated. Methyl androstenediol, a nonmasculinizing male hormone, was given also at the same dosage level. The administration of methyl androstenediol at 1 mg/kg body weight per week had none of the effects reported for testosterone.

Two heifers that were injected with testosterone showed no heat cycles. However, 30 days following cessation of testosterone treatment, these heifers bred and conceived. They were given testosterone during gestation and showed no apparent ill effects until delivery, when difficult parturition occurred. One calf, presumed to be genetically a heifer, was markedly abnormal in its genetalia, showing pronounced testosterone effects (Floyd *et al.*, 1957; Mason *et al.*, 1957, 1958b; Bogart *et al.*, 1958). It is presumed that the testosterone injected into the cow crossed the placenta and influenced the developing heifer calf.

Methyl testosterone when fed at from 0.25 to 1 kg daily did not increase rate of gain or feed efficiency, but it did show some effects on the endocrine glands and accessory sex organs in steers (Krueger *et al.*, 1954). The use of such feed additives as stilbestrol (Kercher *et al.*, 1956; Bohman and Wade, 1958), chlortetracycline (Bohman *et al.*, 1957), and arsenicals (Kline *et al.*, 1949) has resulted in increased rate and efficiency of gains.

Blood enzyme studies

Kidwell *et al.* (1955, 1957) studied the relation of blood glutathione level to rate and efficiency of gains. Although there was a small relation between blood glutathione level and subsequent feed efficiency, the authors concluded that this blood constituent level would not be an accurate index to rate and economy of gains.

Serum alkaline and acid phosphatase activities in calves prior to the feed test did not show any sex, line, or breed differences. Also, activities of these two phosphatases during this period showed no relation to performance traits.

Serum alkaline and acid phosphatase activities after the calves were put on feed test were positively correlated with rate of gain. The heifers of all lines showed a strong correlation between alkaline phosphatase activitiy and rate of gain. A consistent, significant relationship did not exist between acid phosphatase activity and rate of gain or between alkaline phosphatase activity and rate of gain of bulls. There were breed, line, and sex effects observed for both acid and alkaline phosphatase activity. Alkaline phosphatase activity was higher in 2-year-old cows than in older ones. Acid phosphatase activity did not show a change with age of cow. Serum inorganic phosphate levels showed a peak at three months of age after which they declined with age of the animal (Alexander *et al.*, 1958; Johnston *et al.*, 1961, 1962).

Use of small laboratory animals for basic studies

Small animals have been used at some of the stations for the development and testing of basic concepts, principles, and methods in animal breeding which can some day be applied to the improvement of beef cattle. Also, small animals are used for assay of biological material obtained from beef cattle.

Some very important results were obtained when all possible crosses were made among four inbred strains of mice. One of the strains apparently had a high requirement for some of the vitamins (biotin and/or folic acid) in the B complex but was low in thyroid function so this strain produced young satisfactorily. Another strain was hyperthyroid but had a low requirement for these vitamins. Thus, in one strain cross it was almost impossible to raise any young, although fertility was about normal. Crossbreds of these two strains inherited the high requirement plus the high metabolic rate, which created a need that was not normally met. By injecting the mothers of these crossbreds or the young crossbreds themselves with biotin and folic acid, it was possible to relieve all deficiency symptoms and obtain normal growth and survival.

It was established by this investigation that inheritance, nutrition, and endocrines are interrelated in their effects on growth and well-being of the animal (Mason *et al.*, 1956a, b). These interrelations surely raise a question about the value of bulls for use under range conditions when these bulls have been raised and selected under highly desirable conditions. These studies show also that when physiological disturbances develop as a result of crossing, negative heterosis may be the consequence rather than the heterotic effect generally expected from crossbreeding.

Rollins and Cole (1952) reported that most of the variability in ovary weight in rats was lost with inbreeding, which suggested that 80 to 85% of the variability in ovary weights is due to inheritance. They observed that a highly inbred strain gave five to seven times the precision in bioassays as randomly bred rats. Carroll and Gregory (1962) found that pituitary material from dwarf and normal cattle gave the same growth response when injected into dwarf mice. This suggested that dwarfism in mice and in dwarf cattle arises from different causes.

Physiology of circulation and respiration

Heart function has been studied from electocardiograms (Figure 2) taken on normal calves at 500 to 800 pounds body weight, on calves suffering from white muscle disease (Krueger and Van Arsdel, 1959; Van Arsdel *et al.*, 1960a, b), and on various representatives of the dwarf complex using several combinations of leads. Concurrent with the electrocardiograms, heart sounds (Van Arsdel *et al.*, 1956) have been recorded. There are line and sex effects discernible in the normal group at both 500 and 800 pounds body weight.

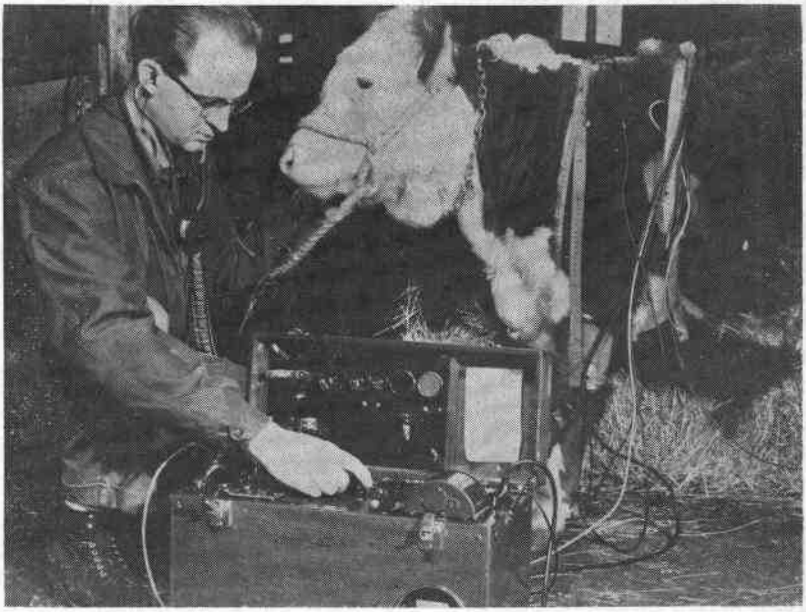

Figure 2. Taking and analyzing electrocardiograms has increased our knowledge regarding the relation of heart function to performance in beef cattle. (Courtesy of Oregon State University.)

One of the major contributions in this study has been the development of the proper leads for taking EKG recordings. Also, the analysis of normal records for establishment of normal values with which deviations may be compared has been necessary (Van Arsdel *et al.*, 1959, 1960a, b; Krueger and Van Arsdel, 1959; Krueger *et al.*, 1960). In all cases in which complete electrocardiographic studies have been made on abnormal animals that were later autopsied, the proper diagnosis by use of the EKG records had been made as revealed by autopsy records (Van Arsdel *et al.*, 1957). It appears that this method of assessing heart function has great possibilities. It also is evident from the data so far that abnormalities in heart function occur at a reasonably high frequency in cattle (Van Arsdel and Bogart, 1961), and that these abnormalities in heart function are in some cases responsible for poor performance or sudden or otherwise unexplained deaths that occur. Van Arsdel and Bogart (1962) and Ratarasarn *et al.* (1961) have shown that ambient temperature affects rectal temperature in smaller calves to a greater extent than in larger animals. Heart rates were not correlated with rectal temperature. Heart rates are influenced by diet; they are higher on heavy feeding of a pelleted ration than when animals are fed largely on hay.

Higher heart rates and body temperatures of young growing cattle are associated with more rapid rates of gains (Williams *et al.*, 1953, 1954). It appears that rapid growth is associated with a slight elevation in metabolic rate which results in increases in heart rate and in body temperature. There is also the possibility that in selecting for rapidly gaining cattle, there has been a selection of rapidly gaining striated muscle but not of rapidly gaining heart muscle. This may have led to a rapid heart with a relatively long systolic period and a relatively short diastolic period. The latter suggests approaching a duration inadequate for circulation of cardiac tissues. This may lead to the necessity for selecting for larger hearts commensurate with increases in other muscle tissue.

Blood groups in beef cattle

The blood groups in beef cattle have been studied by Stroble *et al.* (1954), Mason and Stroble (1954), and Stroble and Hilston (1955). There are blood group differences among lines. Performance data, particularly rate of gain, were studied in relation to blood groups to see if there were demonstrable correlations. This study has not located any relationship between blood groups and performance.

Digestibility of feed in relation to rate and efficiency of gains

It would appear logical that if animals vary in their abilities to digest feed, these variations should be reflected in variations in rate and efficiency of gains. Digestion coefficients have been determined by fecal collections in a digestion stall, by chromogen fecal and feed ratios from grab samples, and by feeding chromic oxide and making fecal and feed ratio determinations of it. No relationship has been established between digestibility coefficients and rate or efficiency of gains (Nelms *et al.*, 1954, 1955).

It should be pointed out that all methods for determining digestibility of feed are inaccurate. The failure to establish a relationship between digestibility and rate or efficiency of gains demonstrates that this relationship, if it exists, cannot be established without more refined techniques for determining digestibility. It does not demonstrate the nonexistence of such a relationship.

Vitamin A utilization and storage

The University of Arizona, in cooperation with the San Carlos Indian Agency, the USDA, and the U. S. Range Livestock Experiment Station made intensive studies on liver and blood carotene and vitamin A levels as they relate to genetic groups of cattle. These studies involved the relationship of vitamin A and carotene in the liver and blood plasma (Diven *et al.*, 1960b) and the effects of varying intakes of carotene and vitamin A on liver and plasma values (Page *et al.*, 1958). Heritability estimates were determined at 230 days of age by the paternal half-sib method from data on progeny from 13 sires (Diven *et al.*, 1960a) as follows: Liver vitamin A, 0.44 for bulls and 0.72 for heifers; liver carotenoids, 0.0 for bulls and 0.35 for heifers; plasma vitamin A, 0.0 for bulls and 0.25 for heifers; plasma carotenoid, 0.13 for bulls and 0.28 for heifers. It appears that certain genetic groups of cattle are superior to others in their ability to make use of the carotene on ranges.

Type Studies, Conformation Scores, and Body Measurements

A number of studies have been made in which type or size have been related to carcass traits and production traits.

Stonaker *et al.* (1952a) concluded that when comprest and conventional-type cattle were fed to a live animal or slaughter steer grade of Low Choice there was no difference in feed efficiency between the two types. The conventional-type cattle ate more, gained more, and weighed 20% more at slaughter finish than the comprest steers. There was little difference in percentage of lean, bone, and fat, but carcasses from conventional-type steers were much heavier (Schleicher *et al.*, 1950; Macleod *et al.*, 1952).

Kidwell and McCormick (1956) found that large-type animals grew faster and more economically than small-type animals. Carcasses from the larger animals contained a higher proportion of bone and muscle and a smaller proportion of fat. Wholesale cuts were proportionally about the same for the two types of cattle.

Knox and Koger (1946) compared large-, medium-, and small-type steers (Figure 3). They concluded that steers that were classed as rangy when put on feed weighed more, gained more, and yielded a higher dressing percentage than the small-type steers, with the medium type intermediate in each case. Average carcass grades were the same for each type. From this work it appears that the development of rapid gaining strains will be more difficult if size is reduced by too greatly restricting height and length to secure compactness.

Knox (1957) pointed out that breeding for short legs and bodies merely results in small cattle, and that beef may be produced more

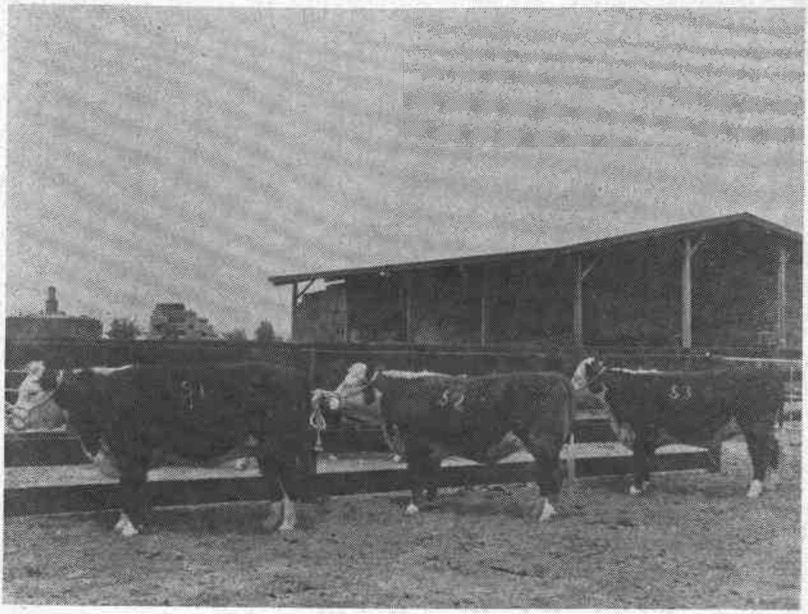

Figure 3. Large-, medium-, and small-type cattle used at the New Mexico station in their comparison of cattle of the three types. (Courtesy of New Mexico State University.)

cheaply by rapidly growing cattle which reach the desired weight at younger ages when less feed is required per unit of gain.

Knox (1954) summarized the studies at New Mexico in which compact cattle were compared with large-type cattle in lifetime productivity. The large-type cattle produced a larger percent calf crop over a longer productive life and the calves weighed more at weaning than calves from compact cows. Thus, the average lifetime production of the two groups was 5.0 calves from the compact cows and 6.5 calves from the large-type cows. Average weight of calf produced per year of cow in the herd was 340 pounds for the compact cows and 440 pounds for the large-type cows. On the basis of calf production per year per 1,000 pounds of cow, the large-type cows averaged 413 pounds and the compact cows averaged 366 pounds. Knox pointed out that several costs are on a per cow basis.

Stonaker *et al.* (1952b) compared winter hay consumption of large-, intermediate-, and compact-type cattle to determine relative costs of wintering the three types of cows and replacement females. There were no differences in feed eaten per unit of body weight for the three types of cattle. Also, Washburn *et al.* (1948) compared compact and conventional types of Shorthorn cattle and found no difference between the two types in food capacity per unit of body weight or in digestibility. However, the conventional cattle were growing more, while the compact cattle were fattening. Consequently, the conventional-type cattle exhibited greater ability to utilize digested dry matter during growth.

With respect to scores and grades, most of the research workers in the Western Region have scored cattle at weaning time and at completion of the feed test, considering that score for type and conformation would be indicative of carcass merit. However, most research indicates that grade at weaning may have little or no relation to production or carcass traits (Kidwell *et al.*, 1957, 1959). In general, scores for type and conformation show little relationship to rate of gain during either the preweaning or postweaning periods, as reported by Knapp and Clark (1951), MacDonald and Bogart (1955), and Koch and Clark (1955b). However, heritability estimates by regression of offspring on dam and half-sib correlations (Koger and Knox, 1952) indicate that selection would be effective in bringing about changes in body form.

Pahnish *et al.* (1961a) reported significant differences for conformation scores between sire progeny groups. Ternan *et al.* (1959) concluded that a total score is as useful in evaluating an animal as detailed scores on the various parts. There is some evidence that scores for type and conformation or condition at the end of the feed test are associated with how well the calf has done, whereas earlier scores are not indicative of how rapidly and efficiently an animal will gain (Durham and Knox, 1953; Romo and Blackwell, 1954; Bogart *et al.,* 1956).

Shelby *et al.* (1955) estimated the heritability of slaughter grade at 0.42 and carcass grade at 0.16. Rollins and Wagnon (1956b) found a higher heritability for weaning grade in a herd that was supplemented than in one that was not supplemented on a range that was somewhat nutritionally deficient during the fall and winter. Kidwell *et al.* (1959) and Ternan *et al.* (1959) studying relationships between conformation scores and body measurements found that most of the simple correlations were low or insignificant.

Bogart *et al.* (1956) found that calves that are smaller in heart girth, have less chest depth, and are longer in body gain more rapidly and efficiently. Kidwell (1955) pointed out that many of the correlations among body measurements result from the effect of size on each of the measurements. Kidwell *et al.* (1959) found that body measurements are not related to rate and efficiency of gains, but they are related to economic factors. Safley *et al.* (1950) found indications that narrower steers gained more efficiently than wider steers

Table 4. HERITABILITY ESTIMATES FOR SLAUGHTER GRADE, SHRINK, AND CARCASS TRAITS

Trait	Heritability	Reference
Slaughter grade	0.63	Knapp and Nordskog, 1946b
	.45	Knapp and Clark, 1950
	–.14	Behrens *et al.*, 1955
	.42	Shelby *et al.*, 1955
	.88	Blackwell *et al.*, 1962
	.35	Shelby *et al.*, 1963
Shrink	.91	Shelby *et al.*, 1955
	.50, .53	Shelby *et al.*, 1963
Dressing percent	.01	Knapp and Nordskog, 1946b
	.25	Behrens *et al.*, 1955
	.73	Shelby *et al.*, 1955
	.25	Blackwell *et al.*, 1962
	.57	Shelby *et al.*, 1963
Carcass weight	.92	Blackwell *et al.*, 1962
	.57	Shelby *et al.*, 1963
Carcass grade	.84	Knapp and Nordskog, 1946b
	.33	Knapp and Clark, 1950
	–.50	Behrens *et al.*, 1955
	.16	Shelby *et al.*, 1955
	–.13	Lindholm and Stonaker, 1957
	.59	Blackwell *et al.*, 1962
	.17	Shelby *et al.*, 1963
Fat thickness	.11	Behrens *et al.*, 1955
	.38	Shelby *et al.*, 1955
	.25	Shelby *et al.*, 1963
Marbling	–.88, .04	Behrens *et al.*, 1955
	.05	Harwin *et al.*, 1961
Area of eye muscle	.69	Knapp and Nordskog, 1946b
	.68	Knapp and Clark, 1950
	.50	Behrens *et al.*, 1955
	.72	Shelby *et al.*, 1955
	.26, .46	Shelby *et al.*, 1963
Color of eye muscle	–.05	Behrens *et al.*, 1955
	.31	Shelby *et al.*, 1955
	.49	Shelby *et al.*, 1963
Length of leg	.76	Shelby *et al.*, 1963
Length of body	.46	Shelby *et al.*, 1963

within the compact or conventional types. Behrens *et al.* (1955) concluded that little shifting in external or interstitial distribution of fat could be expected from selection based on visual grading methods because of their low heritabilities.

Carcass Evaluation

Heritability estimates for slaughter grade, shrink, and carcass traits are listed in Table 4. The estimates reported by Behrens *et al.* (1955), Lindholm and Stonaker (1957), and Harwin *et al.* (1961) were based on steers fed to a constant live grade. Estimates by other workers were based on steers fed for fixed periods.

Even though the heritability estimates indicate that variations in some carcass traits may be highly heritable, improvement in carcass traits will be slow. Selection for carcass traits must be accomplished by progeny testing or by selecting for live animal characteristics related to carcass traits. The phenotypic correlations of live animal measurements and scores with carcass traits are not large enough to be relied heavily upon in selecting for carcass traits (Woodward *et al.*, 1954a; Temple *et al.*, 1956; Stonaker, 1958; Brinks *et al.*, 1962b). Genetic, environmental, and phenotypic correlations between production traits and carcass traits have been reported by Blackwell *et al.* (1962) and Shelby *et al.* (1963). Shelby *et al.* (1963) concluded that little correlated response in carcass traits would result from selection for preslaughter traits except for leg and body length.

Schoonover and Stratton (1957) developed a photographic grid technique to measure rib-eye areas (Figure 4).

Kidwell *et al.* (1959) observed no association between tenderness score and fatness, average daily gain, or any of the consumer preference measures in the study. They concluded that flavor of muscle is associated with percent fat, average daily gain, and quality of juice, and that quality of juice is more dependent upon muscle constituents than on fatness.

Matthews and Bennett (1962) reported that feed treatments had a pronounced effect upon characteristics contributing to visual appraisal of quality in both the live animal and the carcass. Feed treatments did not have any significant effect upon tenderness of the beef when measured organoleptically or with the Warner-Bratzler shear. Tenderness was not directly affected by preslaughter rate of gain in cattle less than 18 months of age.

Rate of gain and feed efficiency appear to be positively related to percent of lean and negatively related to the amount of fat (Stroble

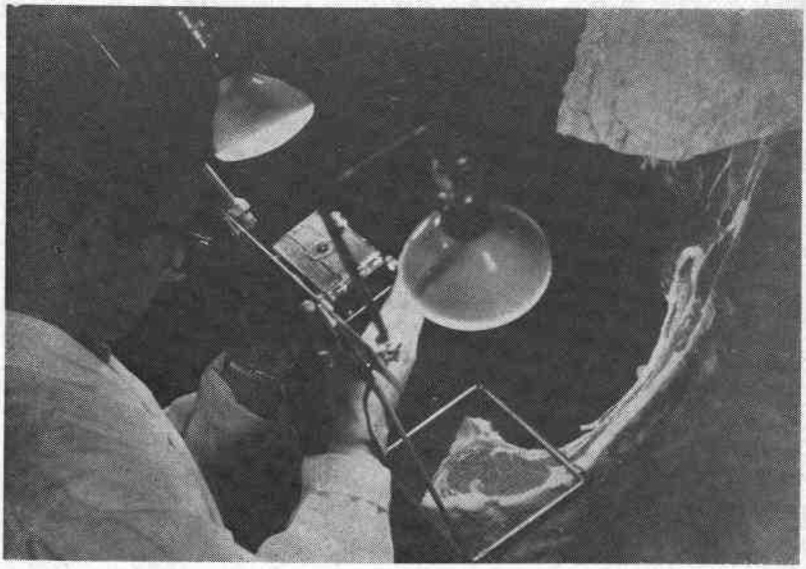

Figure 4. Use of a photographic grid for obtaining a permanent record of the rib-eye area in a carcass. (Courtesy of the University of Wyoming.)

et al., 1951; Willson *et al.*, 1954; Woodward *et al.*, 1954a; Kidwell *et al.*, 1959; Woodward *et al.*, 1959), which would also give a negative relation between rate of gain or feed efficiency and dressing percent or carcass grade. Even live animal grades at slaughter time, although positively related, are not closely correlated with carcass grade. Scores and measurements at weaning appear to have little relation (Kidwell, 1955) or even a negative relation (Durham and Knox, 1953; Hoornbeek *et al.*, 1962) to carcass traits, but they do show some relationship with live animal scores at time of slaughter. Heritability estimates of lean appear high; therefore, selection for more lean should be effective if methods can be developed for measuring the amount of lean in the live animal. The somascope has been used at the Colorado station to measure fat and lean in the live animal.

Carcass cutting yield has long been considered a suitable measure of carcass merit. The ability to predict or actually to alter the proportion of wholesale cuts in the carcass has received considerable attention from research workers in the entire Western Region. Cutout values have been studied in relation to carcass measurements, conformation scores, lines, types, and breeds.

In brief summary, data obtained at the California and Nevada stations show that differences in cutting yields of dairy and beef breeds are small, although the dairy breeds generally have a higher total percentage of round, loin, and rib, and a lower percentage of thin cuts—plate, brisket, flank, and short ribs— (McCormick and Kidwell, 1953). The greatest difference between breeds is primarily the quantity of fat deposited, while the quantity of protein is equal (Ittner *et al.*, 1952). If animal condition is near constant, age of animal (calves, yearlings, two-year-olds) has little influence on the percentage of the various wholesale cuts (Kidwell and McCormick, 1956).

Data from a number of stations indicate that live animal measurements are of limited value in determining carcass measurements or carcass cutouts. Although there may be considerable variation in type and conformation, there is very little difference in the average percentage of wholesale cuts. It does appear that with equal finish the longer, shallower animals will produce a higher percentage of the more demanded cuts and a lower percentage of the cuts in less demand (Stonaker, 1958). At a given weight or age, animals of a larger mature size will produce carcasses with a higher proportion of bone and muscle and a lower proportion of fat. Differences in percent of various wholesale cuts are small (Kidwell and McCormick, 1956; Stonaker, 1958).

Correlation analyses of data from the U. S. Range Livestock Experiment Station and the Nevada, Wyoming, Colorado, and New Mexico stations show that ability to make rapid growth in the feedlot has been associated with small but positive improvement in desirable carcass characteristics.

The regression of increase of rib-eye area per 100 pounds of carcass has been determined as 1.27 square inches for bulls and 0.40 square inch for heifers (Wuthier and Stratton, 1957).

Correlation studies with meat quality factors indicate that carcass grade and fat content of carcass are not satisfactory indicators of tenderness. There also is no definite association of production factors with meat tenderness.

Selection procedures for improving production characteristics will not have adverse effects on the carcass.

Performance Testing

Performance testing in beef cattle involves measuring the ability of the animals to produce beef economically. Many factors contribute to economical production of beef. The ability of the animals to thrive and reproduce and to gain rapidly and efficiently under the environmental conditions provided by nature and man is of utmost importance.

Early work with beef cattle provided some basic understanding of performance expression and of techniques for measuring differences in performance ability. Visual appraisal was shown to be rather inaccurate for estimating the ability of beef steers to gain rapidly and efficiently.

Attempts have been made under the W-1 project to identify more accurately the important performance characteristics and to find improved techniques for measuring their expression.

Types of rations

Rations of various types have been tested for feedlot gain measurements. Keith *et al.* (1952) tested different ratios of concentrates to roughage, ranging from four parts concentrates and one part roughage to one part concentrate to three parts roughage. Steer calves on the ratio of concentrates to hay of 2:1 made the most rapid gains, although reasonably good gains were made on all ratios tested.

Foster *et al.* (1953) at Washington fed an all-pelleted ration with fair success. The Oregon station has fed an all-pelleted ration composed of two parts alfalfa hay to one part concentrate with good results and England *et al.* (1961a) reported very satisfactory feed consumption on this ration.

Initial age and weight

Most postweaning feedlot tests are started at the end of an adjustment period of from two to four weeks following weaning. In calves at this stage of development, age and weight are highly related. Pierce *et al.* (1954) reported that age on test had a positive effect on gain on test. Bennett and Matthews (1955), however, found that initial weight did not influence rate of gain where calves were started at eight months of age. Variations in starting weight were not large in this study. Moore *et al.* (1961) found that initial age and initial weight influenced rate of gain. Smith *et al.* (1961) reported high similarity between rate of gain during each 100-pound increment period over a weight range of 500 to 900 pounds. There was a small increase in rate of gain as body weights increased, suggesting that if large differences in weight and age occur, rate of gain will likely be influenced.

Efficiency of gain, as measured by body weight increment per unit of feed consumed, has been found to be strongly related to body size and somewhat related to age. Bennett and Matthews (1955) found that as initial weight increased feed efficiency decreased markedly. Each pound increase decreased gain per 100 pounds of TDN consumed by 0.02 pound. Smith *et al.* (1961) reported large increases in feed required per 100 pounds gain in weight as body weight increased, in both sexes, from 500 to 900 pounds.

England *et al.* (1961b) found that older calves at any given weight are less efficient. Nelms and Bogart (1956) reported that age at beginning of the test influenced efficiency of gains to the extent of an increase of 4.2 pounds of TDN required per 100 pounds gain for each increase of 10 days in age.

Suckling gain influence

Gains during the suckling period have not shown uniform relationship to gains on postweaning feedlot tests. Pierce *et al.* (1954), MacDonald and Bogart (1955), and Sabin *et al.* (1958) concluded that suckling gains cannot accurately predict feedlot gains. It has been observed that when poor environmental conditions exist prior to weaning there may be some compensatory gain during the feedlot test (Knapp and Clark, 1951; Koger and Knox, 1951; Sabin *et al.*, 1961). When environmental conditions are favorable, however, there tends to be a positive relationship between gains made in the two periods.

Age of dam

Age of dam, evidently, has little effect upon postweaning feedlot gains. Sabin *et al.* (1961) found that calves from two-year-old cows were consistently slower gainers, but no influences were present with advancing age. Bennett and Matthews (1955) concluded that age of dam did not influence rate of gain nor did it influence efficiency of gain when proper adjustments were made for initial weight differences.

Sex influence

It has been found that bull calves regularly gain faster than heifer calves in postweaning tests. The magnitude of the difference has been reported as 0.60, 0.66, 0.70, and 0.77 pounds per day in favor of bull calves (Bennett and Matthews, 1955; MacDonald and Bogart, 1955; Nelms and Bogart, 1955).

Numerous reports indicate that bull calves gain more efficiently than heifers (Bennett and Matthews, 1955; Smith *et al.*, 1961). Nelms and Bogart (1955) found that bulls decreased in efficiency faster than heifers as body weight increased, yet the bulls were still more efficient at body weights of 800 pounds. The difference in efficiency between the sexes is rather large. Calculations based on the data presented by the above workers indicate that heifers require from 20 to 25% more feed per pound gain than bulls during the 500- to 800-pound weight period.

Birth weight

Pierce *et al.* (1954) and MacDonald and Bogart (1955) have reported a positive association between rate of gain on test and birth weight. Nelms and Bogart (1955) found an association with efficiency on test with each 10-pound increase in birth weight, reducing TDN per 100 pounds gain by 17 pounds. In an earlier study at the same station (Pierce *et al.*, 1954), economy of gain was not found to be influenced by birth weight. It seems that under some conditions birth weight may influence gain on postweaning test, but the influence is not large enough to make birth weight a reliable predictive tool.

Mature weight

Mature weight was found to be related to both rate of gain and feed per pound of gain (Lickley *et al.*, 1960). Genetic correlations were 0.64 and -.15, respectively. It was concluded that selection for rate of gain can be expected to increase efficiency and mature size in approximately equal amounts. Selection for mature size could be expected to increase rate of gain, but would not substantially affect feed efficiency.

Digestibility

Limited work has been done to measure differences in digestibility as they contribute to differences in rate and efficiency of gains. In work done by Nelms and Bogart (1955) no significant relationship was established for the protein, fiber, ether extract, and dry matter digestion coefficients in regard to rate and efficiency of gains.

Correlation between rate and efficiency of gain

Many workers have observed a relation between rate of gain and efficiency of gain. MacDonald and Bogart (1955) found the correlation to be high when measured through a weight constant period of 500 to 800 pounds. Pierce *et al.* (1954) found that each 0.1 pound increase in gain above the mean saved 23 pounds of TDN per 100 pounds gain. Another study showed significant but slightly lower savings with 1 pound increase in gain saving 65 pounds (corrected) TDN per 100 pounds gain.

While it is definitely established that rate of gain and feed efficiency are rather highly correlated, some caution needs to be taken in assuming that selection for rate of gain would give a corresponding increase in efficiency (Lickley *et al.*, 1960). These authors point out that since efficiency is usually defined as feed divided by gain the result is correlating a ratio with its denominator, and this gives an automatic or spurious correlation.

Field application

Production testing has been instigated in purebred and commercial herds in practically every state. Nearly 1,100 herds involving some 75,000 cattle are actively carrying on a planned program of production testing in the Western Region. Purebred breeders are gain testing bulls at either central testing facilities or on the farm. The on-the-farm type of test has shown the greatest increase, and supervised programs are active in nearly every state. Commercial producers are measuring production in their cow herds, culling the low producers, and selecting replacement heifers on the basis of records. The demand for tested bulls is gradually increasing.

Heritability levels for performance characteristics give confidence that desirable performance will be transmitted to a large degree. Results are now becoming available that give support to this view.

Bulls from herds that have been developed through application of performance testing have been compared to bulls selected by visual appraisal (Willson, 1962). The offspring of the two groups were carried through feedlot tests over a period of years. The progeny of the performance tested bulls regularly gained faster than progeny of the visually selected bulls and returned more money above feed cost. Carcass merit was approximately equal.

One comparison is reported in which certified Montana steer calves (from a herd using tested bulls) were compared with noncertified Montana calves of similar weight that sold for about the same price (Thompson, 1962). The certified steers gained faster at a lower feed cost and netted $16 per head more than the nontested steers. Dressing percentage was nearly equal for the two kinds of steers, and average carcass grades were similar.

These results give evidence that performance characteristics are transmitted and that they do have economic significance. Through widespread use of sires known to have high level of performance and through selecting replacement heifers and culling cows on the basis of performance, more efficient beef production can be a reality.

Hereditary Abnormalities

The hereditary abnormalities discussed in this publication are hereditary modifications, most of which reduce longevity, modify structure or function in a deleterious manner, or otherwise impair the productivity of beef cattle. Contributions of research in the Western Region to the knowledge of these abnormalities are discussed with occasional reference to pertinent regional contributions of an earlier date.

Cancer eye

Long-term studies conducted at California, the U. S. Range Livestock Experiment Station in Montana, and at New Mexico provide information on the incidence of cancer eye and on some of the factors influencing susceptibility to this condition.

About 4.4% of all Hereford cows retained beyond four years of age in one experimental herd were cancer victims (Guilbert *et al.*, 1948). The cancerous growth generally originated on the lower eyelid but sometimes started in the nictitating membrane. The incidence of cancer in another Hereford herd (Woodward and Knapp, 1950) was comparable to the incidence observed by Guilbert *et al.* (1948). Cancer eye developed in 4.7% of the cows observed during a period of 25 years. As a result of still another investigation, Blackwell *et al.* (1956) reported that cancer eye first appeared in Herefords at four years of age and that the incidence increased with age thereafter.

Evidence of an inherited susceptibility to cancer eye was obtained from the studies previously cited. Guilbert *et al.* (1948) observed that pigmentation of the eyelids suppressed cancer; however, many animals with nonpigmented eyelids remained sound. The authors, therefore, suspected that genetic differences in susceptibility or differences in exposure to some influential environmental factor were involved. The average incidence of cancer eye in three closed lines of Herefords varied from 4.7 to 10.2% ($P < .02$) according to Woodward and Knapp (1950). Line differences and an observed tendency for cancer eye to develop in descendents of afflicted animals led to a conclusion that the condition is partially under genetic control. These earlier conclusions were supported by the work of Blackwell *et al.* (1956) who estimated the heritability of cancer eye by the four methods given below.

Method	*Heritability estimate*
Paternal half-sib correlation	0.17
Intra-sire regression of daughter on dam	0.29
Regression of offspring on sire	0.30
Regression of offspring on dam	0.22

Bloat

Bloat has long posed a problem for beef cattle producers and feeders. Bogart (1962) reported that chronic bloating is highly heritable. Animals that have experienced chronic bloating when mated together or to closely related animals have produced offspring showing an incidence of chronic bloating of 65%.

Semihairlessness

California workers (Kidwell and Guilbert, 1950) described a semihairless condition in a polled Hereford herd. This nonlethal abnormality was characterized by a deficiency of hair, a thick hide, poor fattening ability, and slow growth. A pedigree analysis of the herd indicated that a single autosomal recessive gene was responsible. The condition was believed to be a recurrence of an abnormality reported by workers elsewhere at an earlier date.

Vaginal and uterine prolapse

Woodward and Quesenberry (1956) reported that 93 cases of vaginal or uterine prolapse were associated with 7,859 births in the range Hereford herd at the U. S. Range Livestock Experiment Station in Montana over a period of about 20 years. Yearly incidence of prolapse varied from none to 2.7%. Effects of age of cow on the occurrence of this condition were unimportant. Significant differences in incidence among 11 lines of cattle were considered indicative of a hereditary susceptibility to vaginal or uterine prolapse. Appropriate culling was, therefore, suggested as a partial control measure. It was noted, however, that plane of nutrition or specific nutritional differences may be contributing factors.

Double cervix

A congenital malformation, "double cervix," was reported by California workers (Sittmann *et al.*, 1961). This condition, investigated in two closely related herds and in a third herd with some of the same ancestry, was described as a persistence of the median walls of the Mullerian ducts. The sex-limited abnormality was believed to be due to a single autosomal recessive gene with low penetrance and variable expressivity. Evidence indicated that the "double cervix" had no significant detrimental effect on conception or parturition.

Stillbirths

From a total of 8,857 births over a period of 20 years in the beef cattle herd at the U. S. Range Livestock Experiment Station in Montana, Woodward and Clark (1959) reported that 3.6% yielded stillborn calves. Although no single factor was cited as a major cause of stillbirths, several contributing factors were noted. Increased mortality at birth was associated with the male sex, with inbreeding, with twinning, and with posterior presentations. First-calf heifers produced a higher percentage of stillborn calves than did older cows. Few lethals were identified, but the possibility of inaccurate diagnosis was recognized.

Spastic calves

Stonaker (1958) reported that 2 of the 12 progeny obtained by mating one sire to his own daughters exhibited a spastic condition. This lethal condition was believed to be of genetic origin, but the exact mode of inheritance was not evident from the data available. Spasticity was considered to be the most serious lethal encountered by Colorado workers in their research with inbred stock.

Wry calves

California workers (Gregory, 1954) reported two "wry types" in beef calves. One of these abnormal types, observed in both the Angus and Hereford breeds (Figure 5), was believed to be allied with the dwarfism discussed later. It is, therefore, discussed in con-

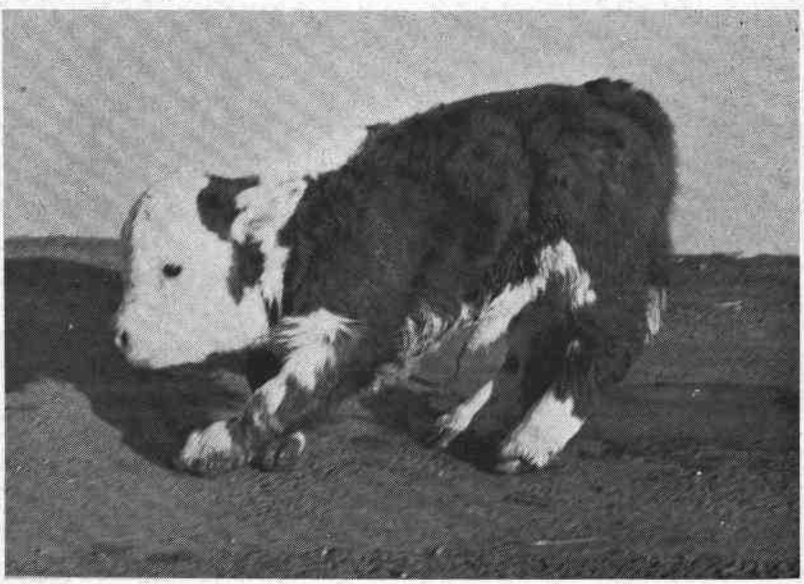

Figure 5. A "wry type" with deformed forelegs, sometimes found associated with the short-headed form of dwarfism. (Courtesy of the University of California, Davis.)

Figure 6. A "wry type" believed to be the result of faulty nutrition of the dam during the gestation period. (Courtesy of the University of California, Davis.)

junction with dwarfism. The second "wry type," observed in Hereford cattle only, exhibited no dwarf characteristics. The incidence in some herds was reported to be as high as 15%. This second type (Figure 6) was characterized by a crooked spine, crooked forelegs, and enlarged knee joints. A wry neck and cleft palate may be present. The investigators suspected faulty nutrition of the dam at some critical point during gestation as the causative factor.

Albinism

A form of albinism appearing in a small Hereford herd was described by Washington investigators (Hafez *et al.*, 1958b; O'Mary and Ensminger, 1959). In general, the condition was characterized by the absence of pigmentation in the skin, muzzle, and hoofs, except for slightly pigmented areas on the inside of the rear legs. The authors implied that a "ghost pattern" of the Hereford was apparent in at least some cases. These calves showed photophobia in sunlight. It was suggested that albinism is an inherited lethal; however, the mode of inheritance and the reason for the lethality remained obscure.

Hydrocephalus

An internal hydrocephalus (Figure 7) characterized by a fluid accumulation in the third and lateral ventricles of the calf brain was studied in Oregon by Krueger *et al.* (1955). The condition was observed in stillborn calves or calves that died within one week after birth. Hydrocephalus and enlarged thyroid glands sometimes occurred together, but not always. That hydrocephalus may be a manifestation of hereditary dwarfism, discussed later, was suggested by the Oregon workers. The frequent occurrence of hydrocephalus in dwarf calves was noted in Arizona (Pahnish *et al.*, 1955a, c), but the condition was also found in calves that apparently were not dwarfs. Con-

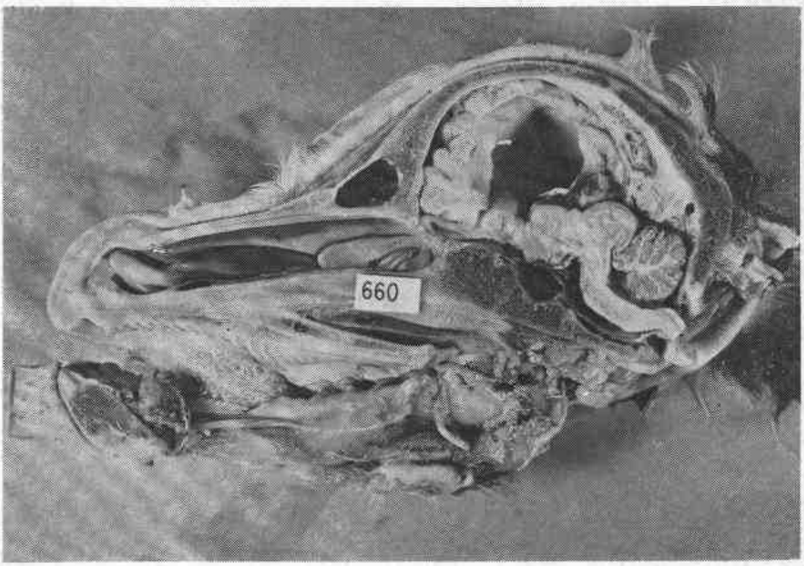

Figure 7. A case of extreme internal hydrocephalus. (Courtesy of the University of California, Davis.)

currently, California workers noted the occurrence of hydrocephalus in dwarf animals, but Tyler *et al.*, (1959) also observed hydrocephalus in calves that showed no evidence of achondroplasia.

Blackwell *et al.* (1959) described a hydrocephalic lethal which appeared in an experimental herd of Hereford cattle in New Mexico. Afflicted calves exhibited marked internal hydrocephalus, a bulging forehead with incomplete ossification of the skull in extreme cases, and incomplete tooth development. Birth weights of hydrocephalic calves averaged about 40 pounds, although most calves were born only a few days prematurely. The abnormal calves were stillborn or died shortly after birth. Those born alive were unable to stand or make direct motor movements. The supraorbital foramina were almost completely occluded. The small foramina were often multiple and distributed about shallow supraorbital grooves. Excessively large amounts of amniotic fluid were associated with the births of a few hydrocephalic calves. Evidence from the herd records supported the hypothesis that a single, autosomal recessive gene is the cause of the hydrocephalic lethal described.

Heart abnormalities

Research at the Oregon station in which EKG records are used to assess heart function (Krueger and Van Arsdel, 1959; Van Arsdel *et al.*, 1959, 1960a; Krueger *et al.*, 1960) reveals a sizable frequency of cardiac insufficiencies in beef cattle. It is suggested that some of the slow rates of gain and sudden deaths result from abnormal heart function.

Dwarfism

The frequent appearance of dwarf calves by 1948, and the resultant concern of beef cattle breeders, prompted investigations of dwarfism that have continued since that date. Information from investigations in the Western Region has been contributed by experiment stations in Arizona, California, Colorado, Nevada, Utah, Washington, and Wyoming.

Because of its relative prevalence, the brachycephalic or short-headed dwarf (Figure 8) first commanded attention. Early efforts were directed toward the description, cause, and control of this dwarf type.

Superficial phenotypic characteristics of the short-headed dwarf were described by Gregory *et al.* (1951c), Lindley (1951), and Pahnish *et al.* (1955c). Characteristics at birth included protrusion of the eyes, continuous protrusion of the tongue, muscular weakness, lack of muscular coordination, and a shortening of the cannon bones

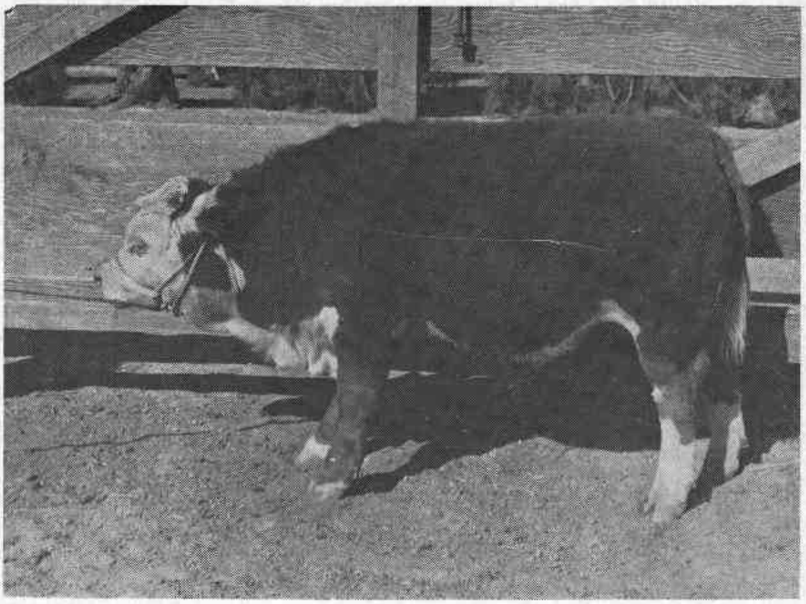

Figure 8. A short-headed (brachycephalic) dwarf. (Courtesy of the University of Arizona.)

in the forelegs. The workers cited generally agreed that this form of dwarfism at a somewhat later stage of development was characterized by a short, broad head, a prominent midforehead region, an undershot jaw, disproportionate enlargement of the abdomen, labored respiration, slow growth, susceptibility to bloat, and high mortality.

Investigations of the cause of the short-headed form of dwarfism by Gregory *et al.* (1953) and Pahnish *et al.* (1955a, c) indicated that a single autosomal recessive gene was basically responsible. This conclusion was consistent with that of workers in other areas of the United States. Although these initial investigations were confined to the Hereford breed, Gregory and Carroll (1956) soon reported evidence of the same deleterious gene in the Aberdeen Angus breed.

While the inheritance of dwarfism was under investigation, it was learned that dwarf animals could reproduce. This provided useful research information (Gregory *et al.*, 1951c; Lindley, 1951; Pahnish *et al.*, 1955a, b). High mortality, difficult parturitions, small stature, and abnormalities in physical conformation were the major deterring factors.

As evidence indicating the hereditary nature of the short-headed form of dwarfism was compiled, control methods were considered.

Kidwell (1951) reported on the probability of detecting a recessive gene by progeny tests, and Pahnish *et al.* (1955c) suggested alternative methods by which cattle breeders could engage in progeny tests for dwarfism.

Included in the early investigations of dwarfism were studies to detect the expression of the dwarf gene in heterozygous animals. A method of recording head profiles for the possible detection of a mid-forehead prominence in heterozygous animals was devised by Gregory and Brown (1952). Gregory *et al.* (1952, 1953) reported that the profiles were reasonably accurate for detection of heterozygous bulls in the horned breeds from which their data were collected.

Since most of the bulls studied by the earlier workers were relatively mature when profiled, Stratton *et al.* (1956) studied the head forms of horned bulls at the ages of 6, 12, and 24 months. Bulls classed as dwarf-free at 6 months of age tended to remain in this classification at the more advanced ages. A high percentage of bulls classed as heterozygous or questionable at 6 months of age moved in the direction of the dwarf-free category by 12 months of age. A high percentage of bulls classed as heterozygotes at 6 months of age were classified dwarf-free at 24 months of age. Classifications at 12 and 24 months of age were in good agreement. The estimated heritability of the discriminant function used in making genetic classifications at 12 months of age was 0.95.

Limitations of the profile technique were suggested when this technique was applied to females and horned bulls from sources other than those used by Gregory *et al.* (1952, 1953). Schoonover and Stratton (1954) met with little success in their attempt to adapt the profile technique to females. Stonaker (1954a, 1958) questioned the validity of the profile classifications of horned bulls on which he used the profile technique. He also compared profile classifications with classifications based on X rays of the lumbar vertebrae. The latter method of detecting heterozygotes was under investigation at the Iowa Agricultural Experiment Station. Stonaker (1958) reported little agreement between the two methods of classification. He also found a typical vertebrae suggestive of heterozygosity in some beef cattle lines, although there apparently was no other evidence that a dwarf-conditioning gene was present in these lines.

As dwarf research progressed, several phenotypically different forms of dwarfism were observed, and hypotheses concerning the modes of inheritance were advanced.

Stonaker (1954a, 1958) reported on a dwarf type obtained by mating comprest cattle *inter se*. These calves differed from the other dwarf types in that the forelegs were generally but not always bowed, and extensions reported to be present on the vertebrae of other dwarfs were absent. The author believed this form of dwarfism to be due to an incompletely dominant autosomal gene.

Gregory (1954) described a "wry-type" found in the Hereford and Aberdeen Angus breeds. This type, exhibiting dwarf characteristics as well as crooked forelegs, was believed to result from the interaction of one compress gene and two recessive dwarf genes.

Genetic relationships of four phenotypically different dwarf types were reported by Gregory (1955). Herefords and Aberdeen Angus dwarfs of the short-headed type, Aberdeen Angus of a long-headed dwarf type, and Shorthorns exhibiting two dwarf types were studied. The F_1 segregates obtained by the various crosses of these four types included dwarf phenotypes plus a compress type. It was, therefore, suggested that various forms of dwarfism are conditioned by the same autosomal recessive gene, accompanied by modifying genes conditioning phenotypic differentiations.

A revision in the classification of dwarf types was indicated by the report of Julian *et al.* (1959). These authors reported the existence of at least four dwarf types consisting of the short-headed or brachycephalic type (Figure 8), the long-headed or dolichocephalic type (Figure 9A), an intermediate type showing some characteristics of the short-headed and long-headed types (Figure 9B), and the compress type (Figure 9C). An addition to this list of dwarf types is suggested by the report of Dexter "bulldog" calves (Figure 10) from long-headed dwarf females when mated to a Dexter bull (Gregory *et al.*, 1960). Hafez *et al.* (1958b) also reported the occurrence of albinism and dwarfism in the same animal, but is was suggested that the two abnormalities may be independent.

When modifications in the expression of the dwarf-conditioning gene were recognized, the reliability of progeny tests for the detection of this gene in heterozygotes was subjected to question (Gregory *et al.,* 1957). The continuation of detailed anatomical and physiological investigations to provide criteria for detecting the dwarf gene and differentiating dwarf types thus was considered justified. Limited investigations in this general area were concurrent with the studies thus far discussed, but most of the anatomical and physiological data have been reported since 1956.

Early endocrine studies by Carroll *et al.* (1951) indicated a deficiency of thyrotropic hormone in the pituitary glands of dwarf calves. These workers reported that the gonadotropic and growth stimulating hormones were about normal in dwarf pituitary glands. Responses of the Snell dwarf mouse to pituitary tissue extract from short-headed dwarfs and from phenotypically normal cattle provided added evidence that the growth stimulating hormone is adequate in the dwarf pituitary (Carroll and Gregory, 1962).

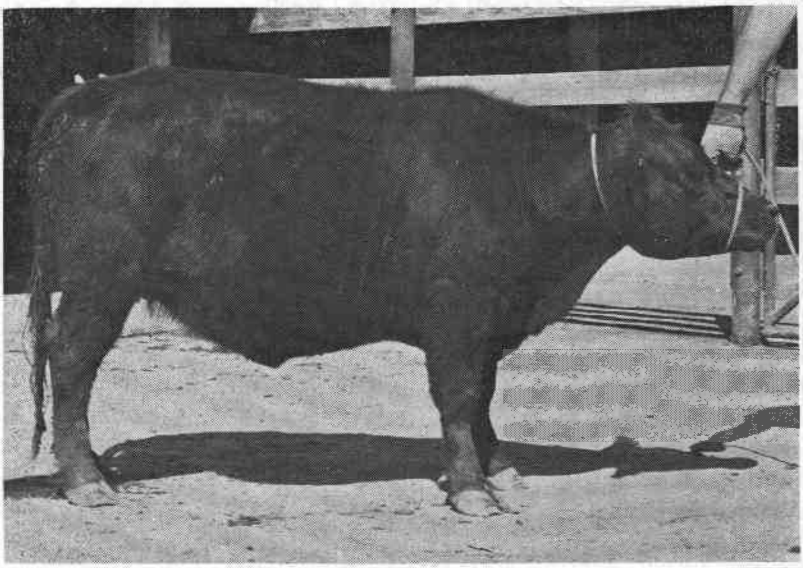

Figure 9A. A long-headed (dolichocephalic) dwarf. (Courtesy of the University of California, Davis.)

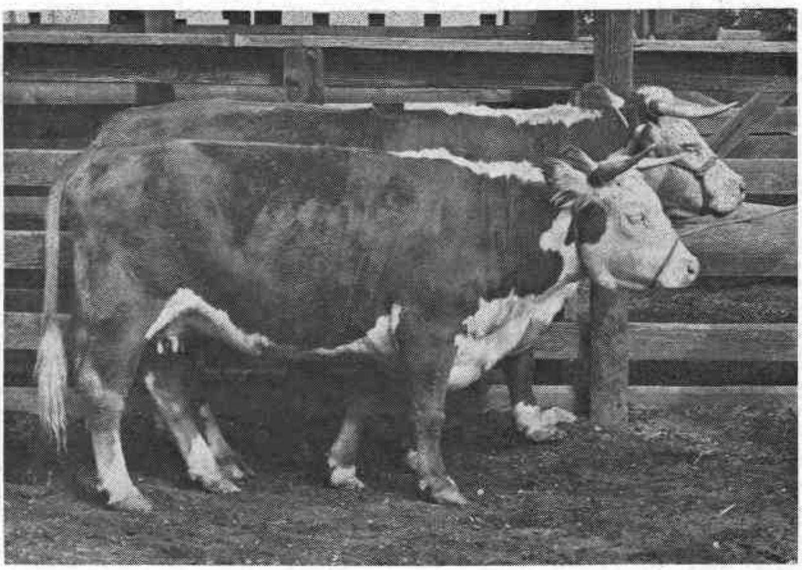

Figure 9B. A mature, intermediate dwarf with a phenotypically normal dam in the background. (Courtesy of the University of California, Davis.)

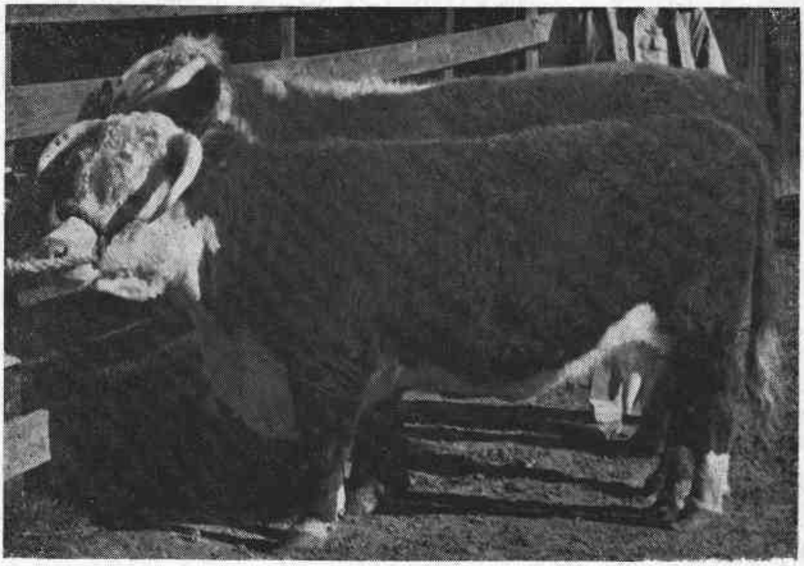

Figure 9C. A mature compress cow with a mature cow of conventional size in the background. The diagnoses of the dwarf and compress animals were verified by post mortem laboratory examinations. (Courtesy of the University of California, Davis.)

Figure 10. A "bulldog" monster produced by mating a Dexter bull with a long-headed dwarf cow. (Courtesy of the University of California, Davis.)

Cornelius *et al.* (1956) conducted chemical and hematological studies on short-headed dwarfs. Serum proteins, calcium, magnesium, and phosphorus were all within the normal ranges. Serum cholesterol and protein-bound iodine were within the normal ranges, suggesting that the short-headed dwarf is not a primary thyroid cretin. Except for differential counts, hematological values appeared normal. In differential counts, lymphocytes and neutrophils differed significantly from normal. Additional information on the blood picture of dwarfs was reported by Hafez *et al.* (1959). Normal values were obtained for blood specific gravity, prothrombin time, sedimentation rate, red cell count, serum creatine, serum creatinine, and electrophoretic patterns of serum proteins. Subnormal values were obtained for blood hemoglobin, hematocrit, and white cell count.

Limited information on the excretion products in the urine of bovine dwarfs has been reported. Asplund *et al.* (1956) found that ranges in ratios of creatinine concentration to glutamic acid concentration in the urine of normal and dwarf calves over two months old were 2.2 to 14.7 and 1.1 to 2.0, respectively. Greater glutamic acid excretion into the urine by dwarfs accounted for the differences in normal and dwarf values. Tyler *et al.* (1962) found chondroitin sulfate-A in the urine of two short-headed dwarfs. This is reported to be the main urinary polysaccharide found in the urine of some human achondroplastic dwarfs as well. The authors, however, found neither chondroitin sulfate-B or heparitin in the urine of the bovine dwarfs, and they concluded that the dwarf syndrome is not homologous with Hurler's syndrome (gargoylism) in humans.

Cytological studies (Leuchtenberger *et al.*, 1956) revealed that the DNA content was more variable in the sperm of dwarf bulls than in the sperm of phenotypically normal bulls. This variation apparently was not due to changes in chromosome number.

Anatomical studies by California workers provided information on the dwarfing process and pointed to skeletal features that these workers believe to be of value in recognizing dwarfism.

Tyler *et al.* (1957) observed disproportionalities in the appendicular skeleton of the short-headed dwarf. The disproportionalities were due to short diaphyses combined with normal ephyseal lengths and bone widths. The most severe disproportionalities occurred in animals up to two months of age. It was concluded that hypoplastic achondroplasia is the dwarfing process and that this process is indicated *in utero*.

Premature fusion of the spheno-occipital synchondrosis in short-headed dwarfs was reported by Julian *et al.* (1957). While fusion in phenotypically normal animals was found to begin at about 24 months of age and terminate by 36 months of age, partial fusion in most dwarfs was apparent at 1 to 18 days of age. Fusion was complete in all dwarfs examined at 5.5 months of age or older.

Tyler *et al.* (1959) reported that two projections into the cranial cavity were common in achondroplastic dwarfs, although a lower incidence was observed also in nonachondroplastic animals. The wing of the orbitosphenoid projected medially and dorsally into the cranial cavity, and the posterior intraoccipital synchondrosis projected medially and anteriorly into the cranial cavity.

Investigations to determine the nature of the articulations of the lumbar vertebrae were conducted by Gregory *et al.* (1961b). The change in articular pattern was reported to be a function of age, with the arthrodial type progressing to the trochlear type. Only the arthrodial type was found in animals up to 122 days of age. A transition from the arthrodial type to the throchlear type occurred between the ages of 4 and 16 months, with the change starting at the anterior end of the lumbar region and progressing posteriorly. The type of articulation was affected little if any by breed, sex, or castration.

Tyler *et al.* (1961) formulated three metacarpal indexes which they considered useful in diagnosing the brachycephalic dwarf type. The indexes were reported to be relatively independent of age or sex, and less than 3.0% of the index values for dwarfs overlapped the values for phenotypically normal controls. The ranges in metacarpal index values were as follows:

	Total length / Diaphyseal length	Total length / Diaphyseal diameter	Diaphyseal length / Diaphyseal diameter
Brachycephalic dwarfs	1.21 to 1.29	3.3 to 3.4	2.7 to 3.8
Control cattle	1.14 to 1.19	4.7 to 7.5	4.1 to 6.4

The influence of achondroplasia on the width and cell content of distal, metacarpal, and epiphyseal lines was investigated by Ticer *et al.* (1961). The zone of resting cartilage in dwarf specimens was narrower and contained fewer cells than did the same zone in the controls ($P < .01$). The zone of proliferation in dwarf animals was relatively wider and contained relatively more cells than did this zone in control stock ($P < .01$).

Gregory *et al.* (1961a) used anatomical diagnostic characteristics to compare short-headed dwarfs from several types of comprest matings with short-headed dwarfs produced by control parents of normal size. They concluded that short-headed dwarfs by comprest parents and by control parents were identical biologically and genetically. Diagnostic characteristics used included projections into the cranial cavity (Tyler *et al.,* 1959), fusion time of the spheno-occipital synchondrosis (Julian *et al.,* 1957), and the three metacarpal indexes previously discussed (Tyler *et al.*, 1961).

Reproductive Physiology

Reproduction in beef cattle is a complex trait. Although efficient reproduction is essential to the beef cattle industry, the evidence to date indicates that reproductive efficiency is very low in heritability. However, there may be various phenomena affecting reproductive processes which are sufficiently high in heritability to be of importance in a beef cattle breeding program.

Stonaker (1954b) found that outbred cows weaned 30% more calves than did inbred cows when bred to inbred bulls.

Also, several studies have indicated that there are specific genes which may cause complete sterility in the female (Gregory *et al.,* 1951b; Kidwell *et al.*, 1954). In both cases the condition was reported to be caused by a single sex-limited, autosomal recessive gene. Other reproductive abnormalities reported to be inherited as simple autosomal recessives are prolonged gestation (Gregory *et al.,* 1951a) and double cervix (Sittmann *et al.,* 1961).

Warnick (1955) investigated the interval from parturition to first estrus in beef cows. He found an interval of 59.2 days in Angus cows and 62.7 days in Hereford cows. Line of breeding, breed, and age of cow had little effect on the length of the interval, and the length of the interval apparently had little effect on subsequent fertility. Christian *et al.,* (1956) reported that vitamin A deficiency did not affect materially the interval from calving to involution of the uterus, but that the interval to first post partum ovulation was longer in vitamin A deficient cows. They also reported that early weaning of calves (2 weeks of age) shortened the post partum interval to first ovulation by 17.7 days but not the interval to involution of the uterus.

The level of winter nutrition was reported to affect both the percentage calf crop and the pounds of calf per cow at weaning time (Hubbert and Sawyer, 1951). They reported that feeding only a limited amount of meadow hay during the winter feeding period of 130 days resulted in a lower percentage calf crop and fewer pounds of calf per cow at weaning than feeding adequate amounts of meadow hay or meadow hay plus concentrates.

Rollins *et al.* (1956) investigated some of the factors responsible for causing variation in gestation length in a herd of inbred cattle. They reported that additive genetic variation between calves and between dams each accounted for approximately 30% of the phenotypic variation in gestation length. Length of gestation was not associated with inbreeding of the calf.

An analysis of the components of variation in length of the calving interval in a herd of range beef cattle where year-round calving was practiced revealed that the length of calving interval was not heritable (Brown *et al.*, 1954). Also, they failed to find a correlation between the length of successive calving intervals for the same cow, which indicates that the length of calving interval is not repeatable.

Christian (1957) reported that beef heifers first exhibit estrus at approximately 12 months of age. He observed that most heifers show considerable follicular development prior to puberty and that approximately 20% ovulate at least once prior to first detectable estrus.

Little experimental work has been reported on reproductive performance in dwarf beef animals. Pahnish *et al.* (1955b) indicated that dwarf animals can be used in beef breeding research. However, they found that dwarf bulls were hampered in natural service because of incoordination. Dwarf females did not conceive readily and in most cases experienced difficult parturition.

Reproductive physiology of the beef bull has not received as much attention as that of the cow, even though it is essential that they produce adequate numbers of viable spermatozoa if satisfactory reproductive levels are to be maintained. Cupps *et al.* (1957) found no difference between semen samples collected with the electroejaculator and the artificial vagina in percent motile sperm, percent live sperm, or percent abnormal sperm. They did find lower sperm concentration and lower levels of fructose and citric acid in those samples collected with the electroejaculator. Salsbury *et al.* (1960) investigated the feasibility of collecting semen from young beef bulls with the electroejaculator and the fertility of this semen after freezing. They obtained only slightly more than 25% conception in 60 females from semen collected with the electroejaculator and frozen for a period of time before use. While the conception rate was low, it does indicate that the semen of the young beef bull is capable of fertilization after being frozen.

Summary

Within the Western Region, 41 lines of cattle from the principal beef cattle breeds are being studied. Most of the lines are being subjected to varying degrees of inbreeding. Inbreeding has resulted in the following findings:

(1) Increased homozygosity (uniformity).

(2) The merits of some inbred lines have been demonstrated. Experimentally derived bulls have sired progenies 5 to 10% more productive than progenies sired by outbred bulls. These are conservative estimates.

(3) Significant negative association of daily gain with inbreeding. However, lines differ in degree to which they resist this depressing effect. Selection is more effective in preventing inbreeding depression on postweaning gains than on preweaning gains.

(4) Sexes differ with respect to depression of birth and weaning weight as inbreeding increases. Females are affected more markedly than males.

(5) Number of stillbirths is higher in inbreds than in outbreds.

(6) Inbred lines differ with respect to blood groups (antigens). As inbreeding increases, loss of antigens is significantly greater than would be expected to result from increased homogeneity.

(7) Uncovered abnormalities such as dwarfism, hydrocephalus, spastics, cross-eye and double eyelid, depressed temple, double cervix, heart defects, cancer eye in certain lines, and vaginal prolapse.

Heritability estimates have been established for the most important commercial traits. These estimates for the most part are positive, and if applied effectively should lead to a constant rate of improvement in the desired characteristics.

Heavy calves at birth generally gain more rapidly than light calves.

Growth of calves has the same linear expression during different periods when the environment is constant. Under stress conditions, growth during one period may be negatively related to growth during other periods.

Rapidly and economically gaining calves have lower levels of blood amino acid and urea nitrogen, and excrete less urea through the urine. Apparently these animals have greater ability to draw amino acids from the blood stream and build them into muscle growth.

Fast gaining animals have a higher content of thyrotropic hormone in their pituitaries than slower gaining animals.

Selection for increased weaning weights appears to be much more effective under optimum conditions than under suboptimum conditions, especially if the suboptimum conditions are quite adverse.

Gains made in feedlot or slaughter weight when adjusted to a common age basis are highly heritable.

Scores for type, conformation, and body measurements show little relationship to rate of gain during either preweaning or postweaning periods; there is some evidence that longer-bodied animals gain more rapidly than those that are larger in heart girth and shorter in body.

Mature body size in cows is highly heritable. Larger cows tend to produce calves that gain more rapidly throughout the growing period.

Feed efficiency is highly correlated with rate of postweaning gain.

Weight for age is preferred over feed test gain as a criterion for improvement.

Sire X station interactions in rate and efficiency of gains emphasize the importance of standardized and refined procedures if comparative sire ratings are employed in a breed improvement program.

Hybrid vigor from crossing inbred lines has reached as high as 20%.

Failure to demonstrate a relationship between digestibility and rate or economy of gain emphasizes the need for more refined techniques for determining digestibility.

Some genetic groups of cattle are superior to others in their ability to make use of carotene (vitamin A) on ranges.

Abnormalities in heart function occur at a fairly high frequency in cattle. These abnormalities are in some cases responsible for poor performance. Higher heart rates and body temperatures of young growing cattle are associated with more rapid rates of gain.

Conventional-type cattle ate more, gained more, were more economical, and weighed 20% more at slaughter finish than compress or small-type steers. Beef can be produced more cheaply by rapidly growing cattle which reach the desired weight at younger ages with less feed required per unit of gain.

Large-type cows produce a larger percent calf crop over a longer productive life, and their calves weigh more at weaning time than calves from compact cows.

Flavor of muscle is associated with percent fat, average daily gain, and quality of juice. Quality of juice is more dependent upon muscle constituents than on fatness.

Feed treatments have a pronounced effect upon characteristics contributing to the visual appraisal of quality in both the live animal and the carcass. Feed treatments had no significant effect upon tenderness of beef. Tenderness was not directly affected by preslaughter rate of gain in cattle less than 18 months of age.

Live animal measurements are of limited value in determining carcass measurements or carcass cutouts.

The W-1 project has stimulated extensive application of production testing in the field. Approximately 1,100 herds involving over 75,000 cattle are under active planned programs of production testing.

Literature Cited

Alexander, G. I., Hugo Krueger, and Ralph Bogart. 1958. Rate and efficiency of gains of beef cattle. V. Serum phosphatases of growing Hereford and Angus calves. Oreg. Agr. Exp. Sta. Tech. Bull. 42.

Alexander, G. I., and Ralph Bogart. 1959. Effect of inbreeding on performance characteristics in inbred lines of cattle. Proc. West Sect. Am. Soc. An. Prod., *10:*VIII.

Alexander, G. I., D. A. Price, Ralph Bogart, and Hugo Krueger. 1959. Rate and efficiency of gains in beef cattle. VII. Hematology of growing Hereford and Angus calves. Oreg. Agr. Exp. Sta. Tech. Bull. 47.

Alexander, G. I., and Ralph Bogart. 1961. Effect of inbreeding and selection on performance characteristics of beef cattle. J. Animal Sci., *20:*702.

Ampy, Franklin, James S. Brinks, Ralph Bogart, and R. T. Clark. 1961. The relationship between serum protein and growth in calves. Proc. West. Sect. Am. Soc. An. Prod., *12:*LXXXII.

Ampy, Franklin, and Ralph Bogart. 1962. Some physiological studies on growth and feed efficiency in beef cattle (*Bos domesticus*). Am. Zool., *2:*170.

Asplund, R. O., J. A. Bennett, and D. J. Matthews. 1956. Observations of glutamic acid excretion in relation to dwarfism and age of cattle. Proc. West. Sect. Am. Soc. An. Prod., *7:*LXIII.

Bailey, C. M., and F. F. Gilbert. 1962. Factors affecting performance traits of Hereford calves in lines developed in two environments. Proc. West. Sect. Am. Soc. An. Prod., *13:*XXII.

Behrens, W. C., H. H. Stonaker, M. H. Hazaleus, and N. L. Landblom. 1955. The genetic and phenotypic relationship between estimates of fat deposition in Hereford steers. Proc. West. Sect. Am. Soc. An. Prod., *6:*49.

Bennett, James A., and Doyle J. Matthews. 1955. Performance testing studies with beef cattle. Utah Agr. Exp. Sta. Bull. 377.

Bhannasiri, Tim, Ralph Bogart, and Hugo Krueger. 1961. Hemoglobin and blood cells of growing beef cattle. J. Animal Sci., *20:*18.

Blackwell, R. L., David E. Anderson, and J. H. Knox. 1956. Age incidence and heritability of cancer eye in Hereford cattle. J. Animal Sci., *15:*943.

Blackwell, R. L., and Paul Hurt. 1956. Relationship between intensity of red color and performance in Hereford cattle. Proc. West. Sect. Am. Soc. An. Prod., *7:*LXII.

Blackwell, R. L., J. H. Knox, and C. E. Shelby. 1957. Genetic components of variance and covariance in weaning, yearling, and feedlot performance of Hereford steers. J. Animal Sci., *16:*1018 (Abstr.).

Blackwell, R. L., J. H. Knox, and Paul V. Hurt. 1958. Effect of age of dam on weaning weight, long yearling weight and postweaning gains of beef cattle. Proc. West. Sect. Am. Soc. An. Prod., *9:*XLII.

Blackwell, R. L., J. H. Knox, and Estel H. Cobb. 1959. A hydrocephalic lethal in Hereford cattle. J. Heredity, *50:*143.

Blackwell, R. L., J. H. Knox, C. E. Shelby, and R. T. Clark. 1962. Genetic analysis of economic characteristics of young Hereford cattle. J. Animal Sci., *21:*101.

Bogart, Ralph, and Robert L. Blackwell. 1950. More beef with less feed. Oreg. Agr. Exp. Sta. Bull. 488.

Bogart, Ralph, A. C. Warnick, J. J. Dahmen, and M. J. Burris. 1951. The effect of the male sex hormone on rate of gain and feed efficiency of beef cattle. J. Animal Sci., *10:*1073 (Abstr.).

Bogart, Ralph, G. E. Nelms, R. W. Mason, D. A. Price, C. E. Shelby, and R. T. Clark. 1955. Body measurements, scores, gains, and feed efficiency of growing beef cattle. J. Animal Sci., *14:*1175 (Abstr.).

Bogart, Ralph, G. E. Nelms, D. A. Price, C. E. Shelby, and R. T. Clark. 1956. Correlations involving body measurements, scores, and certain production traits in beef cattle. Proc. West. Sect. Am. Soc. An. Prod., *7:*LVII.

Bogart, Ralph, Frank Hudson, Hugh Nicholson, R. W. Mason, and Hugo Krueger. 1958. Effect of injected testosterone on fertility in female cattle and sheep. Internatl. J. Fert., *3:*105.

Bogart, Ralph. 1962. Beef cattle breeding research at Oregon State University. Oreg. Agr. Exp. Sta. Misc. Paper 132.

Bohman, V. R., M. A. Wade, and J. E. Hunter. 1957. The effect of chlortetracycline, stilbestrol, and animal fat on fattening steers. J. Animal Sci., *16:*833.

Bohman, Verle R., and Marven A. Wade. 1958. The effect of certain feed additives on the tissues of fattening beef cattle. J. Animal Sci., *17:*124.

Brinks, J. S., R. T. Clark, N. M. Kieffer, and J. R. Quesenberry. 1962a. Mature weight in Hereford range cows—heritability, repeatability, and relationship to calf performance. J. Animal Sci., *21:*501.

Brinks, J. S., R. T. Clark, N. M. Kieffer, and J. R. Quesenberry. 1962b. Genetic and environmental factors affecting performance traits of Hereford bulls. J. Animal Sci., *21:*777.

Brown, L. O., R. M. Durham, Estel Cobb, and J. H. Knox. 1954. An analysis of the components of variance in calving intervals in a range herd of beef cattle. J. Animal Sci., *13:*511.

Burgess, J. B., Nellie L. Landblom, and H. H. Stonaker. 1954. Weaning weights of Hereford calves as affected by inbreeding, sex, and age. J. Animal Sci., *13:*843.

Burris, M. J., Ralph Bogart, A. W. Oliver, and Andrea O. Mackey. 1952. The effect of testosterone propionate on rate of gain, feed efficiency and carcass quality of beef heifers and steers. J. Animal Sci., *11:*789 (Abstr.).

Burris, Martin J., and Ralph Bogart. 1953. The effect of testosterone on the thyrotropic hormone content of the anterior pituitary gland of beef calves. Proc. West. Sect. Am. Soc. An. Prod., *4:*VII.

Burris, Martin J., Ralph Bogart, and Hugo Krueger. 1953a. Alteration of activity of thyroid gland of beef cattle with testosterone. Proc. Soc. Exp. Biol. Med., *84:*181.

Burris, Martin J., Ralph Bogart, and A. W. Oliver. 1953b. Alteration of daily gain, feed efficiency, and carcass characteristics in beef cattle with male hormones. J. Animal Sci., *12:*740.

Burris, Martin J., Ralph Bogart, A. W. Oliver, Andrea Overman Mackey, and J. E. Oldfield. 1954. Rate and efficiency of gains in beef cattle. I. The response to injected testosterone. Oreg. Agr. Exp. Sta. Tech. Bull. 31.

Carroll, F. D., P. W. Gregory, and W. C. Rollins. 1951. Thyrotropic hormone deficiency in homozygous dwarf beef cattle. J. Animal Sci., *10:*916.

Carroll, F. D., W. C. Rollins, and N. R. Ittner. 1955. Brahman-Hereford crossbreds and Herefords—gains, carcass yields, and carcass differences. J. Animal Sci., *14:*218.

Carroll, F. D., and P. W. Gregory. 1962. Responses of the Snell dwarf mouse to pituitary tissue from a bovine dwarf mutant. Proc. Soc. Exp. Biol. Med., *109:*35.

Castle, E. N., Joe D. Wallace, and Ralph Bogart. 1961. Optimum feeding rates for wintering weaner calves. Oreg. Agr. Exp. Sta. Tech. Bull. 56.

Christian, R. E., W. K. Roberts, and I. A. Dyer. 1956. The effect of vitamin A and energy deficiencies on some post partum reproductive phenomena in the cow. Proc. West. Sect. Am. Soc. An. Prod., *7:*LV.

Christian, R. E. 1957. Age at puberty and related phenomena in the beef heifer. Proc. West. Sect. Am. Soc. An. Prod., *8:*XLII.

Clark, R. T., C. E. Shelby, J. R. Quesenberry, R. R. Woodward, and F. S. Willson. 1958. Production factors in range cattle under Northern Great Plains conditions. USDA Tech. Bull. 1181.

Cobb, Estel H., Oliver Wayman, and Valentino Arganosa. 1961. Phenotypic correlations between conformation scores and liveweights at 8, 12, and 20 months of age and rate of gain in beef cattle. Proc. West. Sect. Am. Soc. An. Prod., *12:*XIX.

Cornelius, C. E., W. S. Tyler, and P. W. Gregory. 1956. Chemical and hematological studies on blood of bovine dwarfs. Proc. Soc. Exp. Biol. Med., *92:*522.

Cupps, P. T., D. F. Rahlmann, B. McGowan, and W. C. Rollins. 1957. A comparative evaluation of bovine semen following collection with artificial vagina and the electrojaculator. Proc. West. Sect. Am. Soc. An. Prod., *8:*VIII.

Dahmen, Jerome J., and Ralph Bogart. 1952. Some factors affecting rate and economy of gain in beef cattle. Oreg. Agr. Exp. Sta. Tech. Bull. 26.

deBaca, R. C., Ralph Bogart, W. A. Sawyer, and Farris Hubbert, Jr. 1959. The expression of growth for environmental influences affecting gains of steers. J. Animal Sci., *18:*1536 (Abstr.).

Diven, R. H., O. F. Pahnish, C. B. Roubicek, E. S. Erwin, and H. M. Page. 1960a. Heritability of vitamin A and carotenoid concentrations in bovine liver and plasma. J. Animal Sci., *19:*1218 (Abstr.).

Diven, R. H., O. F. Pahnish, C. B. Roubicek, E. S. Erwin, and H. M. Page. 1960b. Vitamin A and carotenoid interrelationships in bovine plasma and liver. J. Dairy Sci., *43:*1632.

Durham, R. M., and J. H. Knox. 1953. Correlations between grades and gains of Hereford cattle at different stages of growth and between grades at different times. J. Animal Sci., *12:*771.

England, Noah, James S. Brinks, Ralph Bogart, and R. T. Clark. 1961a. Evidence for genetic influence on appetite in beef cattle. J. Animal Sci., *20:*905.

England, Noah, James S. Brinks, Ralph Bogart, David England, and R. T. Clark. 1961b. Factors affecting calf weight gains during the suckling period. Proc. West. Sect. Am. Soc. An. Prod., *12:*IX.

Floyd, Stewart, Frank Hudson, Hugh Nicholson, R. W. Mason, Ralph Bogart, and Hugo Krueger. 1957. Passage of testosterone across mammalian placentae. Oreg. Acad. Sci. Proc. (Abstr.).

Foster, D. E., M. W. Galgan, and M. E. Ensminger. 1953. Pelleted vs. non-pelleted rations for beef cattle. Wash. Agr. Exp. Sta. Circ. 232.

Galgan, M. W., W. E. Ham, and M. E. Ensminger. 1956a. The use of radio-iodine to identify rapid gaining beef animals. Wash. Agr. Exp. Sta. An. Husb. Circ. No. 56-3.

Galgan, M. W., W. E. Ham, and M. E. Ensminger. 1956b. Possible use of radio-iodine in identifying rapid gaining beef animals. Proc. West. Sect. Am. Soc. An. Prod., *7:*LIX.

Gregory, P. W., S. W. Mead, and W. M. Regan. 1951a. A genetic analysis of prolonged gestation in cattle. Portugaliae Acta Biologica, Series A., R. B. Goldschmidt Volumen, p. 861.

Gregory, P. W., S. W. Mead, W. M. Regan, and W. C. Rollins. 1951b. Further studies concerning sex-limited genetic infertility in cattle. J. Dairy Sci., *34:*1047.

Gregory, P. W., W. C. Rollins, P. S. Pattengale, and F. D. Carroll. 1951c. A phenotypic expression of homozygous dwarfism in beef cattle. J. Animal Sci., *10:*922.

Gregory, P. W., and B. B. Brown. 1952. A profilometer for studying head form of the bovine. J. Animal Sci., *11:*700.

Gregory, P. W., W. C. Rollins, and F. D. Carroll. 1952. Heterozygous expression of the dwarf gene in beef cattle. The Southwestern Vet., *5:*345.

Gregory, P. W., C. B. Roubicek, F. D. Carroll, P. O. Stratton, and N. W. Hilston. 1953. Inheritance of bovine dwarfism and the detection of heterozygotes. Hilgardia, *22:*407.

Gregory, P. W. 1954. An analysis of wry calves in California beef herds. J. Animal Sci., *13:*957 (Abstr.).

Gregory, P. W. 1955. The genetic relationships of phenotypically different bovine dwarfs. J .Animal Sci., *14:*1182 (Abstr.).

Gregory, P. W., and F. D. Carroll. 1956. Evidence for the same dwarf gene in Hereford, Aberdeen Angus, and certain other breeds of cattle. J. Heredity, *47:*107.

Gregory, P. W., L. M. Julian, and W. S. Tyler. 1957. The validity of dwarf-carrier cows as testers for the major dwarf conditioning gene. J. Animal Sci., *16:*1028 (Abstr.).

Gregory, P. W., W. S. Tyler, and L. M. Julian. 1960. Evidence that the Dexter mutant is genetically related to recessive achondroplasia. Anat. Rec., *138:*353 (Abstr.).

Gregory, P. W., L. M. Julian, and W. S. Tyler. 1961a. Comparisons of achondroplastic brachycephalic dwarf segregates from comprest and control stocks. Am. Zoologist, *1:*107.

Gregory, P. W., W. S. Tyler, and L. M. Julian. 1961b. Bovine achondroplasia. 4. Articulation of lumbar vertebrae in brachycephalic dwarfs. Growth, *25:*265.

Guilbert, H. R., A. Wahid, K. A. Wagnon, and P. W. Gregory. 1948. Observations on pigmentation of eyelids of Hereford cattle in relation to occurrence of ocular epitheliomas. J. Animal Sci., *7:*426.

Guilbert, H. R., and P. W. Gregory. 1952. Some features of growth and development of Hereford cattle. J. Animal Sci., *11:*3.

Haaby, E. S., N. W. Hilston, and C. P. Stroble. 1952. Beef bull feeding trial. Proc. West. Sect. Am. Soc. An. Prod., *3:*V.

Hafez, E. S. E., D. W. Fletcher, and C. C. O'Mary. 1958a. Physiochemical and microbiological studies on homozygous dwarfs. J. Animal Sci., *17:*1140 (Abstr.).

Hafez, E. S. E., C. C. O'Mary, and M. E. Ensminger. 1958b. Albino-dwarfism in Hereford cattle. J. Heredity, *49:*111.

Hafez, E. S. E., M. E. Ensminger, and W. E. Ham. 1959. Morphological and physio-chemical studies on dwarf Herefords. J. Agr. Sci., *53:*339.

Ham, Wendell E., M. W. Galgan, and M. E. Ensminger. 1954. Blood levels of protein bound iodine as an indicator of potential rate of gain in beef cattle. Proc. West. Sect. Am. Soc. An. Prod., *5:*293.

Harris, L. A., L. C. Faulkner, and H. H. Stonaker. 1960. Effect of inbreeding on the estimated breeding soundness of yearling Hereford bulls. J. Animal Sci., *19:*665.

Harwin, G. O., H. H. Stonaker, and M. H. Hazaleus. 1961. Factors associated with marbling in yearling beef carcasses. Proc. West. Sect. Am. Soc. An. Prod., *12:*XX.

Hitchcock, Glen H., W. A. Sawyer, Ralph Bogart, and Lyle Calvin. 1955. Rate and efficiency of gains in beef cattle. III. Factors affecting weight and effectiveness of selection for gains in weight. Oreg. Agr. Exp. Sta. Tech. Bull. 34.

Hoornbeek, F. N., J. A. B. McArthur, Ralph Bogart, and W. H. Kennick. 1962. Performance and carcass characteristics in beef cattle. Proc. West. Sect. Am. Soc. An. Prod., *13:*XXXII.

Hubbert, F. Jr., and W. A. Sawyer. 1951. The influence of winter nutrition on range beef cattle production in eastern Oregon. Proc. West. Sect. Am. Soc. An. Prod., *2:*109.

Hubbert, Farris Jr., W. A. Sawyer, E. N. Hoffman, Ralph Bogart, and A. W. Oliver. 1955. Braham X Hereford crossbred vs. Herefords under eastern Oregon range conditions. Oreg. Agr. Exp. Sta. Bull. 549.

Ittner, N. R., H. R. Guilbert, and F. D. Carroll. 1952. Rate and efficiency of gain, carcass value, and climatic adaptability of Hereford, Brahman, Hereford X Brahman, and Hereford X Shorthorn crossbred cattle. Proc. West. Sect. Am. Soc. An. Prod., *3:*VI.

Johnston, W. K. Jr., A. F. Anglemier, and Ralph Bogart. 1961. Apparent patterns of certain blood enzymes in Hereford and Angus cattle. Proc. West. Sect. Am. Soc. An. Prod., *12:*XCI.

Johnston, W. K. Jr., A. F. Anglemier, Ralph Bogart, and Marilyn Mack. 1962. Relation of certain blood enzymes to rate of gain in Hereford and Angus cattle. Proc. West. Sect. Am. Soc. An. Prod., *13:*III.

Julian, L. M., W. S. Tyler, T. J. Hage, and P. W. Gregory. 1957. Premature closure of the spheno-occipital synchondrosis in the horned Hereford dwarf of the "short-headed" variety. Am. J. Anat., *100:*269.

Julian, L. M., W. S. Tyler, and P. W. Gregory. 1959. The current status of bovine dwarfism. J. Am. Vet. Med. Assn., *135:*104.

Keith, T. B., R. F. Johnson, and W. P. Lehrer, Jr. 1952. The optimum ratio of concentrate to alfalfa hay for fattening steers. Idaho Agr. Exp. Sta. Bull. 290.

Kercher, C. J., P. O. Stratton, C. O. Schoonover, N. W. Hilston, M. W. Glenn, and E. J. Thiessen. 1956. The effect of stilbestrol on the performance and carcasses of steers. Proc. West. Am. Soc. An. Prod., *7:*XXXI.

Kidwell, James F., and H. R. Guilbert. 1950. A recurrence of the semihairless gene in cattle. J. Heredity, *41:*190.

Kidwell, James F. 1951. The number of progeny required to test a male for heterozygosity. J. Heredity, *42:*215.

Kidwell, James F., P. W. Gregory, and H. R. Guilbert. 1952. A genetic investigation of allometric growth in Hereford cattle. Genetics, *37:*158.

Kidwell, James F. 1954. Some growth relations in range cattle. J. Animal Sci., *13:*54.

Kidwell, J. F., LeGrand Walker, and J. A. McCormick. 1954. Hereditary female sterility in Holstein-Friesian cattle. J. Heredity, *45:*142.

Kidwell, James F. 1955. A study of the relation between body conformation and carcass quality in fat calves. J. Animal Sci., *14:*233.

Kidwell, James F., Marven A. Wade, and James E. Hunter. 1955. The relation of blood glutathione level to growth and body size in beef cattle. Proc. West. Sect. Am. Soc. An. Prod., *6:*43.

Kidwell, James F., and John A. McCormick. 1956. The influence of size and type of growth and development of cattle. J. Animal Sci., *15:*109.

Kidwell, J. F., V. R. Bohman, M. A. Wade, and J. E. Hunter. 1957. The effect of nutritional environment on blood glutathione level in beef cattle. Growth, *21:*1.

Kidwell, J. F., P. R. Ternan, J. E. Hunter, J. M. Harper, C. E. Shelby, and R. T. Clark. 1959. Relations among conformation scores, body measurements, and production factors of yearling steers. Nev. Agr. Exp. Sta. Tech. Bull. 204.

Kline, E. A., M. E. Ensminger, T. J. Cunha, W. W. Heinemann, and W. E. Ham. 1949. Effect of adding drugs to the ration of fattening cattle. J. Animal Sci., *8*:411.

Knapp, Bradford Jr., and Arne W. Nordskog. 1946a. Heritability of growth and efficiency in beef cattle. J. Animal Sci., *5*:62.

Knapp, Bradford Jr., and Arne W. Nordskog. 1946b. Heritability of live animal scores, grades, and certain carcass characteristics in beef cattle. J. Animal Sci., *5*:194.

Knapp, Bradford Jr., and R. T. Clark. 1947. Genetic and environmental correlations between growth rates of beef cattle at different ages. J. Animal Sci., *6*:174.

Knapp, Bradford Jr., A. L. Baker, and R. T. Clark. 1949. Crossbred beef cattle for the Northern Great Plains. USDA Circ. 810.

Knapp, Bradford Jr., and R. T. Clark. 1950. Revised estimates of heritability of economic characteristics in beef cattle. J. Animal Sci., *9*:582.

Knapp, B. Jr., R. C. Church, and A. E. Flower. 1951a. Genetic history of Line 1 Hereford cattle at the U. S. Range Livestock Experiment Station, Miles City, Montana. Mont. Agr. Exp. Sta. Bull. 479.

Knapp, Bradford Jr., R. C. Church, and A. E. Flower. 1951b. Genetic improvement in a line of Hereford cattle. J. Animal Sci., *10*:1026 (Abstr.).

Knapp, Bradford Jr., and R. T. Clark. 1951. Genetic and environmental correlations between weaning scores and subsequent gains in the feed lot with record of performance steers. J. Animal Sci., *10*:365.

Knox, J. H., and Marvin Koger. 1946. A comparison of gains and carcasses produced by three types of feeder steers. J. Animal Sci., *5*:331.

Knox, J. H., W. E. Watkins, Marvin Koger, and K. A. Valentine. 1951. Research on the college ranch. New Mexico Agr. Exp. Sta. Bull. 359.

Knox, J. H. 1954. The effect of type on: Rate and efficiency of gains, early maturity, carcass excellence and cow production. W. S. C. Stockmen's Handbook. *1954*:16.

Knox, J. H. 1957. The interrelations of type, performance, and carcass characteristics. J. Animal Sci., *16*:240.

Koch, Robert M., and R. T. Clark. 1955a. Influence of sex, season of birth and age of dam on economic traits in range beef cattle. J. Animal Sci., *14*:386.

Koch, Robert M., and R. T. Clark. 1955b. Genetic and environmental relationships among economic characters in beef cattle. I. Correlation among paternal and maternal half-sibs. J. Animal Sci., *14*:775.

Koch, Robert M., and R. T. Clark. 1955c. Genetic and environmental relationships among economic characters in beef cattle. II. Correlation between offspring and dam and offspring and sire. J. Animal Sci., *14*:786.

Koch, Robert M., and R. T. Clark. 1955d. Genetic and environmental relationships among economic characters in beef cattle. III. Evaluating maternal environment. J. Animal Sci., *14*:979.

Koger, Marvin. 1948. First calves forecast production. New Mexico Agr. Exp. Sta. Press Bull. 1026.

Koger, Marvin, and J. H. Knox. 1951. The correlation between gains made at different periods by cattle. J. Animal Sci., *10*:760.

Koger, Marvin, and J. H. Knox. 1952. Heritability of grade and type in range beef cattle. J. Animal Sci., *11*:361.

Krueger, Hugo, Martin J. Burris, and Ralph Bogart. 1954. Methyl testosterone in beef cattle. Am. J. Physiol., *179*:653 (Abstr.).

Krueger, Hugo, John Kaufmes, Ralph Bogart, Paul A. Allen, and L. R. Vawter. 1955. Demonstration: Hydrocephalus, enlarged thyroids, and cervical curvature of the spine associated with early death of calves. Proc. West. Sect. Am. Soc. An. Prod., *6*:123.

Krueger, Hugo, M. A. MacDonald, and Ralph Bogart. 1956. Blood chemical differences between Hereford and Angus cattle. Fed. Proc., *15*:369.

Krueger, Hugo, and Ralph Bogart. 1959. Testosterone inhibition of ovulation in heifers. The Pharmacologist, *1(2)*.

Krueger, Hugo, and W. C. Van Arsdel III. 1959. Lead selection for electrocardiograms in beef cattle. The Physiologist, *2*:74.

Krueger, Hugo, Wm. C. Van Arsdel III, and Ralph Bogart. 1960. QRS and T axes in beef cattle. Fed. Proc., *19*.

Kushwaha, N. S., L. C. Ferguson, and H. H. Stonaker. 1954. Association between inbreeding and antigen occurrence in inbred lines of Hereford cattle. J. Animal Sci., *13*:960 (Abstr.).

Leuchtenberger, Cecilie, Franz Schrader, Sally Hughes-Schrader, and P. W. Gregory. 1956. Certain cytochemical and cytological aspects of dwarfism in cattle. J. Morphol., *99*:481.

Lickley, Charlene R., H. H. Stonaker, T. M. Sutherland, and K. H. Riddle. 1960. Relationship between mature size, daily gain, and efficiency of feed utilization in beef cattle. Proc. West. Sect. Am. Soc. An. Prod., *11*:IX.

Lindholm, H .B., and H. H. Stonaker. 1956. Relative economic importance of traits affecting net income in beef cattle. Proc. West. Sect. Am. Soc. An. Prod., *7*:LVIII.

Lindholm, H. B., and H. H. Stonaker. 1957. Economic importance of traits and selection indexes for beef cattle. J. Animal Sci., *16*:998.

Lindley, C. E. 1951. Observations on midgets in beef cattle. J. Heredity, *42*:273.

Lucas, K., F. X. Gassner, H. H. Stonaker, and S. S. Wheeler. 1950. Relationship of thyroid, adrenal, and pituitary characteristics to body development in small and conventional types of fat Hereford steers. Proc. West. Sect. Am. Soc. An. Prod., *1*:73.

MacDonald, M. A., R. S. Tether, H. M. Krueger, and Ralph Bogart. 1953. Differences in blood amino acids and blood glucose in beef cattle. Proc. West. Sect. Am. Soc. An. Prod., *4:*X.

MacDonald, M. A., and Ralph Bogart. 1955. Relationship between rate and efficiency of gain and type in breeding beef cattle. New Zealand J. Sci. and Tech., *36:*460.

MacDonald, M. A., Hugo Krueger, and Ralph Bogart. 1956. Rate and efficiency of gains in beef cattle. IV. Blood hemoglobin, glucose, urea, amino acid nitrogen, creatinine, and uric acid of growing Hereford and Angus calves. Oreg. Agr. Exp. Sta. Tech. Bull. 36.

Macleod, G. K., H. M. Hazaleus, T. E. Blackburn, H. H. Stonaker, and L. E. Washburn. 1952. Carcass analysis of "comprest" and conventional type Hereford steers. Proc. West. Sect. Am. Soc. An. Prod., *3:*VIII.

Marchello, J. A., D. W. Blackmore, and J. J. Urick. 1960. Heritability of 18-month weight of heifers and its relationship to birth weight and weaning weight of their calves. Proc. West. Sect. Am. Soc. An. Prod., *11:*X.

Mason, R. W., and C. P. Stroble. 1954. A study of blood groups of inbred lines of beef cattle. Proc. West. Sect. Am. Soc. An. Prod., *5:*243.

Mason, R. W., Ralph Bogart, and Hugo Krueger. 1956a. Inherited endocrine relationships affecting fertility in mice. Oreg. Acad. Sci. Proc. (Abstr.).

Mason, R. W., Ralph Bogart, and Hugo Krueger. 1956b. Growth rate, feed efficiency and thyroid activity in male mice of different strains and strain crosses. Proc. West. Sect. Am. Soc. An. Prod., *7:*XLIII.

Mason, R. W., G. Nelms, and Ralph Bogart. 1956c. A urine collecting apparatus for bulls and heifers. Proc. West. Sect. Am. Soc. An. Prod., *7:*XXIII.

Mason, R. W., Hugh Nicholson, Ralph Bogart, and Hugo Krueger. 1957. Testosterone administration to young bovine females prior to pregnancy. J. Pharm. and Exp. Therap., *119.*

Mason, R. W., Ralph Bogart, and Hugo Krueger. 1958a. Methods of adjusting data for differences due to sex. Proc. West. Sect. Am. Soc. An. Prod., *9:*XLI.

Mason, R. W., J. F. Bone, Ralph Bogart, and Hugo Krueger. 1958b. Urogenital anomalies in calf born to beef cow treated with testosterone during pregnancy. J. Pharm. and Exp. Therap., *122:*49A (Abstr.).

Matthews, Doyle J., and James A. Bennett. 1962. Effect of preslaughter rate of gain upon tenderness and other carcass characteristics of beef. J. Animal Sci., *21:*738.

McCleery, Neil B., and R. L. Blackwell. 1954. A study of the effect of mild inbreeding on weaning weight and grade of range calves. Proc. West Sect. Am. Soc. An. Prod., *5:*223.

McCormick, John A., and James F. Kidwell .1953. Producing beef from Holstein steers. Nev. Agr. Exp. Sta. Circ. 3.

Moore, D. B., H. H. Stonaker, and Kent Riddle. 1958. Rates of gain in Hereford bulls as affected by inbreeding, line, age, weight, years, and pens. Proc. West. Sect. Am. Soc. An. Prod., *9:*XLIII.

Moore, Donald B., H. H. Stonaker, and Kent Riddle. 1961. Factors influencing comparisons of Hereford bulls for rate of gain. J. Animal Sci., *20:*255.

Nelms, George, Ralph Bogart, and J. E. Oldfield. 1954. Determination of digestibility in performance testing of beef cattle. Proc. West. Sect. Am. Soc. An. Prod., *5:*123.

Nelms, George E., and Ralph Bogart. 1955. Some factors affecting feed utilization in growing beef cattle. J. Animal Sci., *14:*970.

Nelms, G. E., D. A. Price, and Ralph Bogart. 1955. The relationship of some digestion coefficients to rate and efficiency of gains in growing beef cattle. Proc. West. Sect. Am. Soc. An. Prod., *6:*217.

Nelms, G. E., and Ralph Bogart. 1956. The effect of birth weight, age of dam and time of birth on suckling gains of beef cattle. J. Animal Sci., *15:*662.

Nicholson, H. H., E. N. Hoffman, R. W. Mason, and Ralph Bogart. 1962. Effect of dietary factors upon the thyrotropic hormone content of the anterior pituitary. J. Animal Sci., *21:*549.

O'Mary, C. C., and M. E. Ensminger. 1959. The occurrence of albinism in registered Hereford beef cattle. J. Animal Sci., *18:*1462 (Abstr.).

Page, H. M., E. S. Erwin, T. R. Varnell, and C. B. Roubicek. 1958. Effect of hepatic vitamin A and carotene concentration on the biological value of carotene in the bovine. Am. J. Physiol., *194:*313.

Pahnish, O. F., E. B. Stanley, and C. E. Safley. 1955a. The inheritance of dwarf anomaly in beef cattle. J. Animal Sci., *14:*200.

Pahnish, O. F., E. B. Stanley, and C. E. Safley. 1955b. Breeding history of an experimental herd of dwarf beef cattle. J. Animal Sci., *14:*1025.

Pahnish, O. F., E. B. Stanley, C. E. Safley, and C. B. Roubicek. 1955c. Dwarfism in beef cattle. Ariz. Agr. Exp. Sta. Bull. 268.

Pahnish, O. F., Ralph Bogart, E. B. Stanley, C. B. Roubicek, and C. E. Shelby. 1958a. Adjustment of weaning weights of range calves to a standard age of 270 days. Proc. West. Sect. Am. Soc. An. Prod., *9:*XLVII.

Pahnish, O. F., C. B. Roubicek, E. B. Stanley, Ralph Bogart, and C. E. Shelby. 1958b. The influence of age of dam on the 270-day weaning weights of bull and heifer calves. Proc. West. Sect. Am. Soc. An. Prod., *9:*XLVIII.

Pahnish, O. F., J. S. Brinks, R. T. Clark, and J. R. Quesenberry. 1961a. Range performance of progeny of Miles City sires. J. Animal Sci., *20:*909 (Abstr.).

Pahnish, O. F., C. B. Roubicek, and Farris Hubbert, Jr. 1961b. Influence of sex, sire and environmental factors on protein fractions in the blood serum of range calves. Proc. West. Sect. Am. Soc. An. Prod., *12:*VII.

Pahnish, O. F., E. B. Stanley, Ralph Bogart, and C. B. Roubicek. 1961c. Influence of sex and sire on weaning weights of southwestern range calves. J. Animal Sci., *20:*454.

Pahnish, O. F., R. L. Roberson, R. L. Taylor, C. B. Roubicek, R. T. Clark, and J. R. Quesenberry. 1962. Postweaning performance of progeny of Miles City sires. Proc. West. Sect. Am. Soc. An. Prod., *13:*XXI.

Pierce, Cecil D., H. G. Avery, Martin Burris, and Ralph Bogart. 1954. Rate and efficiency of gains in beef cattle: II. Some factors affecting performance testing. Oreg. Agr. Exp. Sta. Tech. Bull. 33.

Price, D. A., M. A. MacDonald, Ralph Bogart, Hugo Krueger, C. E. Shelby, and R. T. Clark. 1956. Correlations of nitrogeneous and carbohydrate constituents of the blood and urine with rate and efficiency of gains in beef cattle. Proc. West. Sect. Am. Soc. An. Prod., *7:*XLIV.

Price, Donald A., Ralph Bogart, Graham Alexander, and Hugo Krueger. 1957. Red and white cell counts in genetically different groups of beef cattle. J. Animal Sci., *16:*1111 (Abstr.).

Price, D. A., G. I. Alexander, Ralph Bogart, and Hugo Krueger. 1959. Rate and efficiency of gains in beef cattle. VI. Breed, line, and sex differences for some blood constituents of young beef cattle. Oreg. Agr. Exp. Sta. Tech. Bull. 46.

Quesenberry, J. R. 1950. Livestock breeding research at the U. S. Range Livestock Experiment Station. USDA Agr. Information Bull. 18.

Quesenberry, J. R. 1957. Research at the U. S. Range Livestock Experiment Station. Mont. Agr. Exp. Sta. Circ. 216.

Ratarasarn, Sucheep, Wm. C. Van Arsdel III, and Ralph Bogart. 1961. The effect of dietary change on the heart rate of beef calves. Proc. West. Sect. Am. Soc. An. Prod., *12:*LXXXV.

Rollins, W. C., and H. H. Cole. 1952. The relative importance of genetic and environmental factors in determining the precision of gonadotrophin assay. Endocr., *51:*203.

Rollins, W. C., H. R. Guilbert, and P. W. Gregory. 1952. Genetic and environmental factors affecting preweaning growth of Hereford cattle. J. Animal Sci., *11:*743 (Abstr.).

Rollins, W. C., and H. R. Guilbert. 1954. Factors affecting the growth of beef calves during the suckling period. J. Animal Sci., *13:*517.

Rollins, W. C., and K. A. Wagnon. 1955. A genetic analysis of weaning weights in a range beef herd operated under optimum and suboptimum nutritional regimes. Proc. West. Sect. Am. Soc. An. Prod., *6:*35.

Rollins, W. C., and N. R. Ittner. 1956. A comparison of the performance of $\frac{3}{4}$ Hereford—$\frac{1}{4}$ Brahman calves with Hereford calves. Proc. West. Sect. Am. Soc. An. Prod., *7:*LX.

Rollins, W. C., R. C. Laben, and S. W. Mead. 1956. Gestation length in an inbred Jersey herd. J. Dairy Sci., *39:*1578.

Rollins, W. C., and K. A. Wagnon. 1956a. A genetic analysis of weaning weight in a range beef herd operated under optimum and suboptimum nutritional regimes. J. Animal Sci., *15:*125.

Rollins, W. C., and K. A. Wagnon. 1956b. Heritability of weaning grade in range beef cattle. J. Animal Sci., *15:*529.

Rollins, W. C., F. D. Carroll, J. W. T. Pollock, and M. N. Kudoda. 1962. Beef cattle performance and progeny tests for gain, efficiency, carcass conformation, and earliness of maturity. J. Animal Sci., *21:*200.

Romo, Anthony, and R. L. Blackwell. 1954. Phenotypic and genetic correlations between type and weight of range cattle at different periods. Proc. West. Sect. Am. Soc. An. Prod., *5:*205.

Roubicek, C. B., R. T. Clark, and O. F. Pahnish. 1956a. Range cattle production: A literature review. V. Carcass and meat studies. Ariz. Agr. Exp. Sta. Rpt. 143.

Roubicek, C. B., R. T. Clark, R. M. Richard, and O. F. Pahnish. 1956b. Range cattle production: A literature review. IV. Postweaning performance. Ariz. Agr. Exp. Sta. Rpt. 138.

Roubicek, C. B., R. T. Clark, and P. O. Stratton. 1956c. Range cattle production: A literature review. I. Reproduction. Ariz. Agr. Exp. Sta. Rpt. 133.

Roubicek, C. B., R. T. Clark, P. O. Stratton, and O. F. Pahnish. 1956d. Range cattle production: A literature review. II. Prenatal development. Ariz. Agr. Exp. Sta. Rpt. 135.

Roubicek, C. B., R. T. Clark, P. O. Stratton, and O. F. Pahnish. 1956e. Range cattle, production: A literature review. III. Birth to weaning. Ariz. Agr. Exp. Sta. Rpt. 136.

Roubicek, C .B., R. T. Clark, and O. F. Pahnish. 1957a. Range cattle production: A literature review. VI. Maternal factors. Ariz. Agr. Exp. Sta. Rpt. 146.

Roubicek, C. B., R. T. Clark, and O. F. Pahnish. 1957b. Range cattle production: A literature review. VII. Genetics of cattle. Ariz. Agr. Exp. Sta. Rpt. 149.

Roubicek, C. B., R. T. Clark, and O. F. Pahnish. 1957c. Range cattle production: A literature review. VIII. Effects of climatic environment. Ariz. Agr. Exp. Sta. Rpt. 154.

Sabin, S. W., P. O. Stratton, and N. W. Hilston. 1958. Growth from birth to weaning in beef calves as an indication of future performance. J. Animal Sci., *17:*1147 (Abstr.).

Sabin, S. W., P. O. Stratton, and Ralph Bogart. 1961. Genetic-environmental study of calf growth. J. Animal Sci., *20:*911 (Abstr.).

Safley, C. E., H. H. Stonaker, and S. S. Wheeler. 1950. Comparison of small and conventional types of Hereford steers as evaluated by body and carcass measurements. Proc. West. Sect. Am. Soc. An. Prod., *1:*90.

Salsbury, S. W., P. O. Stratton, and G. E. Nelms. 1960. Utilization of frozen semen from young beef bulls. Proc. West. Sect. Am. Soc. An. Prod., *11:*XI.

Sawyer, W. A., Ralph Bogart, and Mohamed M. Oloufa. 1948. Weaning weight of calves as related to age of dam, sex, and color. J. Animal Sci., *7:*514.

Sawyer, W. A., J. C. R. Li, and Ralph Bogart. 1949. The relative influence of age of dam, birth weight, and size of dam on weaning weight of calves. West. Sect. Am. Soc. An. Prod., (Moscow-Pullman).

Schleicher, E. W., H. H. Stonaker, M. H. Hazaleus, and S. S. Wheeler. 1950. Feedlot and carcass characteristics of small and conventional type Hereford steer calves. Proc. West. Sect. Am. Soc. An. Prod., *1:*68.

Schoonover, C. O., and P. O. Stratton. 1954. A study of recessive dwarfism in Hereford females. Proc. West. Sect. Am. Soc. An. Prod., *5:*233.

Schoonover, C. O., and P. O. Stratton. 1957. A photographic grid used to measure rib eye areas. J. Animal Sci., *16:*957.

Shelby, C. E., R. T. Clark, and R. R. Woodward. 1955. The heritability of some economic characteristics of beef cattle. J. Animal Sci., *14:*372.

Shelby, C. E., R. T. Clark, J. R. Quesenberry, and R. R. Woodward. 1957. Heritability of some economic traits in record of performance bulls. J. Animal Sci., *16:*1019 (Abstr.).

Shelby, C. E., R. T. Clark, J. R. Quesenberry, and R. R. Woodward. 1960. Heritability of some economic characteristics in record of performance bulls. J. Animal Sci., *19:*450.

Shelby, C. E., W. R. Harvey, R .T. Clark, J. R. Quesenberry, and R. R. Woodward. 1963. Estimates of phenotypic and genetic parameters in ten years of Miles City R.O.P. steer data. J. Animal Sci., *22:*346.

Sittmann, K., W. C. Rollins, and J. W. Kendrick. 1961. A genetic analysis of the double cervix condition in cattle. J. Heredity, *52:*26.

Smith, Gary, C. C. O'Mary, and M. E. Ensminger. 1961. Rate of gain and feed efficiency within specific weight increments in growing beef cattle. J. Animal Sci., *20:*911 (Abstr.).

Stonaker, H. H. 1951. A unique herd of Hereford cattle; the R. G. Gietz herd has an average *inter se* relationship greater than that between full sibs. J. Heredity, *42:*207.

Stonaker, H. H., M. H. Hazaleus, and S. S. Wheeler. 1952a. Feedlot and carcass characteristics of individually fed compress and conventional type Hereford steers. J. Animal Sci., *11:*17.

Stonaker, H. H., J. F. Ingalls, and S. S. Wheeler. 1952b. Winter hay consumption of breeding females of large, intermediate, and compress types of Hereford cattle. J. Animal Sci., *11:*26.

Stonaker, H. H. 1954a. Dwarfism in beef cattle. Proc. West. Sect. Am. Soc. An. Prod., *5:*239.

Stonaker, H. H. 1954b. Observations on reproduction, growth, feed utilization and grades of inbred and outbred Hereford cattle. J. Animal Sci., *13:*963 (Abstr.).

Stonaker, H. H. 1958. Breeding for beef. Colo. Agr. Exp. Sta. Bull. 501-S.

Stonaker, H. H. 1962. Homogametic heterosis. Proc. West. Sect. Am. Soc. An. Prod., *13:*XXIII.

Stratton, P. O., N. W. Hilston, and C. O. Schoonover. 1956. A study of duplicate head form measurements on horned Hereford bulls at different ages. Proc. West. Sect. Am. Soc. An. Prod., *7:*LXIV.

Stroble, C. P., C. B. Roubicek, and N. W. Hilston. 1951. Carcass studies of steer progeny. Proc. West. Sect. Am. Soc. An. Prod., *2:*155.

Stroble, C. P., R. W. Mason, and N. W. Hilston. 1954. A study of the immunogenetic behaviour of inbred lines of Hereford cattle. J. Animal Sci., *13:*963 (Abstr.).

Stroble, C. P., and M. W. Glenn. 1955. A fatal case of bovine anaphylaxis. J. Am. Vet. Med. Assn., *126:*227.

Stroble, Charles P., and Neal W. Hilston. 1955. A study of the possible association of blood groups and feeding performance of beef cattle. Proc. West. Sect. Am. Soc. An. Prod., *6:*57.

Temple, R. S., H. H. Stonaker, Douglas Howry, Gerald Posakony, and M. H. Hazaleus. 1956. Ultrasonic and conductivity methods for estimating fat thickness in live cattle. Proc. West. Sect. Am. Soc. An. Prod., *7:*LXX.

Ternan, P. R., J. F. Kidwell, J. E. Hunter, C. E. Shelby, and R. T. Clark. 1959. Associations among conformation scores, among body measurements and the relations between scores and measurements in yearling steers. J. Animal Sci., *18:*880.

Thompson, LeRoy. 1962. Impact of performance tested cattle on the cattle feeder. Mont. State Col. Seventh Beef Prod. Sch. Proc.

Ticer, J. W., W. S. Tyler, L. M. Julian, and P. W. Gregory. 1961. Influence of achondroplasia on the width and cell content of an epiphyseal line. Am. Zoologist, *1:*222 (Abstr.).

Tyler, W. S., L. M. Julian, and P. W. Gregory. 1957. The nature of the process responsible for the short-headed Hereford dwarf as revealed by gross examination of the appendicular skeleton. Am. J. Anat., *101:*477.

Tyler, W. S., L. M. Julian, L. S. McFarland, H. E. Evans, and P. W. Gregory. 1959. Two projections into the cranial cavity associated with achondroplastic dwarfism in cattle. Am. J. Vet. Res., *20:*702.

Tyler, W. S., L. M. Julian, and P. W. Gregory. 1961. Bovine achondroplasia. III. Standards of metacarpal indexes for achondroplastic, brachycephalic dwarfs and controls. Am. J. Vet. Res., *22:*693.

Tyler, W. S., P. W. Gregory, and K. Meyer. 1962. Sulfated mucopolysaccharides of urine from brachycephalic bovine dwarfs. Am. J. Vet. Res., *23:*1109.

Urick, J., A. E. Flower, F. S. Willson, and C. E. Shelby. 1957. A genetic study in steer progeny groups during successive growth periods. J. Animal Sci., *16:*217.

Van Arsdel, Wm. C. III, John Weinmann, and Hugo Krueger. 1956. Heart sounds of domestic animals. Proc. West. Sect. Am. Soc. An. Prod., *7:*XLVI.

Van Arsdel, W. C. III, Robert L. Manning, G. I. Alexander, Hugo Krueger, and Ralph Bogart. 1957. Perforation of ventricular septum in beef calf. Oreg. Acad. Sci. Proc. (Abstr.).

Van Arsdel, W. C. III, Hugo Krueger, and Ralph Bogart. 1959. Lead selection, cardiac axes and interpretation of electrocardiograms in beef cattle. Oreg. Agr. Exp. Sta. Bull. 51.

Van Arsdel, Wm. C. III, Hugo Krueger, and Ralph Bogart. 1960a. Vector orientation of P, QRS, and T axes in beef cattle. The Physiologist, *3(3).*

Van Arsdel, Wm. C. III, Hugo Krueger, and J. E. Oldfield. 1960b. Weight losses suggesting nutritional edema in new-born calves. Proc. West. Sect. Am. Soc. An. Prod., *11:*XXVIII.

Van Arsdel, W. C. III, and Ralph Bogart. 1961. Electrocardiograms of 8-year-old Angus cows, one with severe edema. Proc. West. Sect. Am. Soc. An. Prod., *12:*LXXXVI.

Van Arsdel, Wm. C. III, and Ralph Bogart. 1962. Ambient temperatures, heart rates, and rectal temperatures in beef calves. Proc. West. Sect. Am. Soc. An. Prod., *13:*II.

Wagnon, K. A., and W. C. Rollins. 1957. A genetic analysis of long-yearling heifer weights in a range beef herd operated under optimum and suboptimum nutritional regimes. J. Animal Sci., *16:*1026 (Abstr.).

Wagnon, K. A., and W. C. Rollins. 1959. Heritability estimates of postweaning growth to long-yearling age of range beef heifers raised on grass. J. Animal Sci., *18:*918.

Warnick, A. C. 1955. Factors associated with the interval from parturition to first estrus in beef cattle. J. Animal Sci., *14:*1003.

Washburn, L. E., J. Matsushima, H. F. Pearson, and R. C. Tom. 1948. Nutrient utilization by "compact" and conventional type Shorthorn steers. J. Animal Sci., *7:*127.

Williams, C. M., Hugo Krueger, and Ralph Bogart. 1953. Rectal temperatures on performance tested beef calves. Proc. West. Sect. Am. Soc. An. Prod., *4:*VI.

Williams, C. M., Hugo Krueger, and Ralph Bogart. 1954. Heart rates of performance tested beef calves. Proc. West. Sect. Am. Soc. An. Prod., *5:*299.

Willson, F. S., J. J. Urick, and A. E. Flower. 1954. Genetic studies of steer progeny groups slaughtered following three successive feeding treatments. J. Animal Sci., *13:*965 (Abstr.).

Willson, F. S., and A. E. Flower. 1956. Bull indexing as a selection procedure in the improvement of beef cattle. Mont. Agr. Exp. Sta. Bull. 487.

Willson, F. S. 1962. What R.O.P. selected bulls will do for commercial cattle. Mont. State Col. Seventh Beef Prod. Sch. Proc. *1962:*44.

Woodward, R. R., and R. T. Clark. 1950. The repeatability of performance of several Hereford sires as measured by progeny records. J. Animal Sci., *9:*588.

Woodward, R. R., and Bradford Knapp, Jr. 1950. The hereditary aspect of cancer eye in Hereford cattle. J. Animal Sci., *9:*578.

Woodward, R. R., J. R. Quesenberry, R. T. Clark, C. E. Shelby, and O. G. Hankins. 1954a. Relationships between preslaughter and postslaughter evaluations of beef cattle. USDA Circ. No. 945.

Woodward, R. R., J. R. Quesenberry, and F. S. Willson. 1954b. Production and carcass quality in beef cattle. Mont. Agr. Exp. Sta. Circ. 207.

Woodward, R. R., and J. R. Quesenberry. 1956. A study of vaginal and uterine prolapse in Hereford cattle. J. Animal Sci., *15:*119.

Woodward, R. R., and F. J. Rice. 1958. Variation in weight-constant body length measurements of Hereford bulls. J. Animal Sci., *17:*1146 (Abstr.).

Woodward, R. R., and R. T. Clark. 1959. A study of stillbirths in a herd of range cattle. J. Animal Sci., *18:*85.

Woodward, R. R., F. J. Rice, J. R. Quesenberry, R. L. Hiner, R. T. Clark, and F. S. Willson. 1959. Relationships between measures of performance, body form and carcass quality of beef cattle. Mont. Agr. Exp. Sta. Bull. 550.

Wuthier, Paul R., and P. O. Stratton. 1957. The creatinine level of blood serum as an indicator of carcass composition. Proc. West. Sect. Am. Soc. An. Prod., *8:*LII.

Administrative and Research Personnel

ARIZONA AGRICULTURAL EXPERIMENT STATION
R. K. Frevert, Director, Tucson, Arizona.
O. F. Pahnish, W-1 Committeeman, Tucson, Arizona

CALIFORNIA AGRICULTURAL EXPERIMENT STATION
M. L. Peterson, Director, Berkeley, California
W. C. Rollins, W-1 Committeeman, Davis, California

COLORADO AGRICULTURAL EXPERIMENT STATION
S. S. Wheeler, Director, Fort Collins, Colorado, and Administrative Adviser of W-1
H. H. Stonaker, W-1 Committeeman, Fort Collins, Colorado

HAWAII AGRICULTURAL EXPERIMENT STATION
M. M. Rosenberg, Director, Honolulu, Hawaii
Estel H. Cobb, W-1 Committeeman, Honolulu, Hawaii

IDAHO AGRICULTURAL EXPERIMENT STATION
J. E. Kraus, Director, Moscow, Idaho
R. E. Christian, W-1 Committeeman, Moscow, Idaho

MONTANA AGRICULTURAL EXPERIMENTAL STATION
J. A. Asleson, Director, Bozeman, Montana
F. S. Willson, W-1 Committeeman, Bozeman, Montana
N. M. Kieffer, W-1 Committeeman, U. S. Range Livestock Experiment Station, Miles City, Montana

NEVADA AGRICULTURAL EXPERIMENT STATION
D. W. Bohmont, Director, Reno, Nevada
C. M. Bailey, W-1 Committeeman, Reno, Nevada

NEW MEXICO AGRICULTURAL EXPERIMENT STATION
Philip J. Leyendecker, Director, University Park, New Mexico
L. A. Holland, W-1 Committeeman, University Park, New Mexico

OREGON AGRICULTURAL EXPERIMENT STATION
F. E. Price, Director, Corvallis, Oregon
Ralph Bogart, W-1 Committeeman, Corvallis, Oregon

UTAH AGRICULTURAL EXPERIMENT STATION
D. W. Thorne, Director, Logan, Utah
J. A. Bennett, W-1 Committeeman, Logan, Utah

WASHINGTON AGRICULTURAL EXPERIMENT STATION
M. T. Buchanan, Director, Pullman, Washington
C. C. O'Mary, W-1 Committeeman, Pullman, Washington

WYOMING AGRICULTURAL EXPERIMENT STATION
N. W. Hilston, Director, Laramie, Wyoming
G. E. Nelms, W-1 Committeeman, Laramie, Wyoming

BEEF CATTLE RESEARCH BRANCH, ANIMAL HUSBANDRY RESEARCH DIVISION, ARS, USDA
R. T. Clark, Regional Coordinator, Denver, Colorado
J. S. Brinks, Geneticist, Denver, Colorado