UNIVERSITY OF MISSOURI COLLEGE OF AGRICULTURE
AGRICULTURAL EXPERIMENT STATION
RESEARCH BULLETIN 31

SOME FACTORS INFLUENCING THE RATE OF GROWTH AND THE SIZE OF DAIRY HEIFERS AT MATURITY

COLUMBIA, MISSOURI
AUGUST, 1918

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SOME FACTORS INFLUENCING THE RATE OF GROWTH AND THE SIZE OF DAIRY HEIFERS AT MATURITY

C. H. ECKLES AND W. W. SWETT

Probably in no field of investigation connected with agriculture has work in recent years been of greater significance than that concerning the factors connected with the growth of domestic animals. The amount of attention given to this subject is not at all surprising when the limited extent of scientific knowledge of the subject and the tremendous economic importance of the questions involved are considered.

In the dairy herds of the United States alone not less than eight million heifers are on hand at any one time. No less than four million must come to maturity each year to replace dairy cows already in use. The annual cost of raising these heifers is approximately $250,000,000. The grower of dairy cattle is confronted not only with the large expense of raising these animals and of supplying proper rations but with questions as to the possible effect of various factors involved upon the growth and future usefulness of the animals. Examples of these questions are: the influence of gestation and lactation upon the rate of growth; relation of the size of the calf at birth to future development; influence of the age at first freshening upon the size of the cow when mature; the relation of liberality of the ration to rate of growth and size of animal at maturity. The careful observers of dairy cattle in practical herds ask many questions concerning growth, such as what is the cause of the marked variations in the average size of dairy animals of the same breed in different herds and between individuals within a herd.

A consideration of the more practical side of these and certain other questions based upon extensive investigations concerning the growth and development of dairy heifers is found in an earlier publication by the Missouri Experiment Station.[1] The object of this bulletin is to present in a more complete form and with less attention to the practical side of the question involved certain data concerning the factors which influence growth.

Nature of growth.—Mendel[2] says there is no satisfactory definition of "growth". The word, however, is usually understood as indicative of that series of physiological changes by which an individual of any species develops from the fertilized egg to maturity. When the parent cells unite at the time fertilization of the egg takes place, in some manner a force is set free which has been termed by some the "growing impulse", by others the "growth tendency" or "inherent tendency to grow".

According to Minot,[3] the impulse to grow is imparted with the union of the generative cells, and uterine life is characterized by rapid growth. He estimates that in the early embryonic stages rabbits grow as much as 1000 per cent in a day, and that over 98 per cent of the growth impulse is lost before birth. An animal, then, begins ex-uterine life with less than two per cent of the original growth power with which it was endowed.

It seems to be the general opinion that hormones or secretions of ductless glands are responsible for the growth stimulation. Killicott[4] says, "It seems likely that in organisms in general the normal growth of each tissue or of each organ is controlled separately by a specific internal secretion. These substances may regulate growth either thru inhibition or acceleration, and the effect produced may be due either to the presence or the withdrawal of the specific substance." The glands supposed to be especially connected with the phenomena of growth are the thyroid, the pituitary body, the pineal body, and the thymus.

The individual has an inheritance or growth impulse which makes it possible to attain a certain size, and even the greatest intake of food will not cause this limit to be exceeded. Nutrition, which is often looked upon as a controlling factor, can do no more than give free scope to the inherent tendency to grow which the animal has received at birth.

The tendency of the animal body is to grow at a regular but constantly decreasing rate of speed from birth to maturity. In spite of this general tendency which manifests itself under uniform and good conditions, growth is influenced to a considerable extent by the conditions under which the animal is forced to live. The "growth tendency" evidently exists to a greater extent within the skeleton than within the tissues. The body weight of the animal may be influenced very decidedly by a change in conditions, but the upper limit of the skeletal size of an animal is determined by heredity. The stature which an animal may attain within the definite limits fixed by heredity is directly related to the treatment received during its period of growth. Morgan[5] believes it is due to an inhibitory factor developed within the body. Insufficiency of food will result in checking or stopping growth, but this is an abnormal condition.

Investigations concerning growth.—Experiments concerning growth have been conducted generally with small laboratory animals. The work of Osborne and Mendel is based almost entirely upon results with white rats. Hart and McCollum have generally used white rats but report some investigations with swine, fowls and cattle. Aron experimented with dogs, and Waters with cattle and swine. Considerable work, largely of a statistical nature, has also been done with human beings. While the fundamental facts concerning growth as established by the use of laboratory animals are generally assumed to apply to other species, including domestic animals, there is still some uncertainty of the extent to which this is the case. Waters was among the first to report extensive investigations with cattle.

It has been assumed by a few writers that an animal must grow at a maximum rate practically every day from birth to maturity to reach the full stature as fixed by heredity. According to Waters[6] this is only to assume, "that the organism is utterly incapable of compensating for any retarded development at any time in its growth period, either by a subsequently increased rate of growth, or by extending, even the slightest degree, the growth cycle, much less by growing at a time when so sparsely fed that no gain in weight occurs."

It was noted by Waters that the tendency to recover was strong following a period of adverse conditions. After a severe illness of short duration the animal usually increases its rate of growth and compensates for the check in growth. As a rule, the longer the period of adversity the less complete will be the recovery. Whether or not the compensation is ever entirely complete is questionable.

In an experiment carried on by Waters,[7] 15 growing beef animals of different ages were kept for one year on a ration of maintenance, or one which maintained a constant weight without permitting gains. Under such conditions extensive growth of skeleton took place in every case. Aron[8] experimenting with dogs secured similar results. Waters[9] found that an animal which received even less than a maintenance ration made skeleton growth for about six months, after which the growth continued for a time, but varied directly in proportion to the ration given. In these experiments it was noted that the animals on a low nutritive plane developed a form characterized by being abnormally narrow in certain parts. Poor nutrition exerted a more pronounced effect upon the width than upon the height of the animal.

Until recently the nutritional requirements for growth were assumed to be met by a ration which supplied sufficient calories together with a certain amount of protein. As a result there are several feeding standards such as Armsby's, the Wolf-Lehman, and others which undertake to set forth the nutritional requirements. Armsby expresses the requirements in "digestible true protein" and "net energy", while the Wolf-Lehman standard uses "digestible crude protein" and "digestible carbohydrates" and "ether extract."

The mineral demands of the growing body were recognized, but little was known concerning the requirements. It was generally assumed that there was little danger of a shortage in mineral constituents.

As a result of important investigations in recent years, especially those by Mendel and Osborne, and McCollum and Hart, the problem of nutrition is now known to be far more complex.

These investigations have made it clear that the nutritional requirements cannot be expressed in terms of digestible nutrients alone. According to McCollum[10], in addition to sufficient energy, four other factors must be taken into account: (1) Quantity and quality of proteins; (2) character of the inorganic constituents; (3) presence of unidentifed dietary factors, fat soluble A and water soluble B. Nutritive disaster follows if any of these are absent or of an inadequate character. A consideration of these factors in relation to growth of dairy animals does not come within the scope of this paper, except as the question may be raised regarding the possibility of the results reported on the experimental animals used having been influenced by the inadequacy of the ration with reference to some of these nutritional factors.

SOURCE OF DATA

The data upon which this paper is based have been taken on animals in the dairy herd of the University of Missouri. A small portion of the data is from general records kept of the herd. For example, records of the weights of calves at birth and the weights of the dams following parturition have been kept for twelve years. Another portion of the data is obtained from records covering a series of years which have been taken by this Experiment Station for the purpose of determining a normal growth curve of dairy heifers. The animals which supplied this data have been kept under what is considered normal conditions. Up to six months of age the animals received a ration based chiefly upon milk. Whole milk was given for the first two weeks followed by skim milk for the remainder of the period. From the time the heifers were two weeks old, up to first parturition they received, during the winter season, a ration composed of alfalfa hay and corn silage with a small grain allowance in most cases. During the pasturing season the animals were kept on a good blue grass pasture. The object was to maintain the animals in a good thrifty condition but not to allow them to become fat.

The greater part of the material used, however, is based upon data covering eight years which were accumulated during an investigation by this Experiment Station, the objects of which were: (1) To determine the effect of the liberality of the ration during the growing period and; (2) the influence of the age at first calving upon the growth, size at maturity, and milking characteristics of dairy heifers. Forty-two purebred heifers of the Jersey, Holstein, and Ayrshire breeds were used. One-half of these received from birth to time of first parturition what is referred to later as the "heavy ration." This group received whole milk from birth to the time they were six months old. A grain ration consisting of corn and oats, and alfalfa hay was fed practically ad libitum during the winter months, while in summer a portion of the group was on pasture and received in addition a liberal grain allowance.

The second group, referred to later as the "light-fed group", received whole milk for two weeks then skimmilk until they were six months old. Alfalfa hay was fed ad libitum during the winter, and in the summer a part of the group was on pasture. This group was not limited in the amount of food offered; but since it was limited to roughage, the amount of digestible nutrients consumed was far less than that taken by the group which received the ration containing large amounts of concentrates. While the experiment was planned primarily to compare a heavy and a light ration, it was later decided that it was rather a comparison between a very liberal and a moderate ration, since many dairy animals under practical conditions receive a ration inferior to that which was received by the light-fed group.

The factor of age at first calving was introduced by having one-half of both the heavy and light-fed groups calve at what would be an early age for the breed, and the remainder at what would be a late age. The Jerseys averaged 22.7 months for the early and 34.9 months for the late-calving group. The averages for the Holsteins were 23 months for the early, and 34.3 months for the late-calving group. After parturition all were placed on the same ration which consisted of an abundance of silage and hay, with an allowance of a grain mixture of 4 parts corn, 2 parts bran, 1 part oil meal. The grain mixture was fed in proportion to the amount of milk produced.

It is believed all requirements for an adequate ration as laid down by McCollum were met in these rations. The alfalfa hay supplied an abundance of calcium and of the growth accessory, fat soluble A, also plenty of protein known to be efficient when fed with grain. The corn supplied ample phosphorus, and together with the oats a liberal amount of the water soluble B. The animals which received the alfalfa alone showed every evidence of being well nourished and were in the best of health. It was noticeable that the group which received the liberal ration appeared decidedly older and better developed than the light-fed group at the same age.

Weights and Measurements.—In the investigation concerning factors which influence the growth of dairy heifers, reference to which has been made, the animals were weighed monthly. In the first part of the experiment they were weighed on the day nearest the middle of the calendar month. Later, as a result of the extreme variations in weights which appeared from month to month in data taken in this manner, the plan was changed to include weighings on three successive days at the middle of the month; and the average of these weights was used as the correct figure. This plan was continued until the animals were dropped from the experiment, at which time they were from six to eight years old. The same plan has been followed in taking the weights for determining the normal growth, except that as a result of experience the plan was modified to include monthly weights up to parturition. After parturition, weights for three days were taken and again six months after parturition. A series of monthly weights were thus obtained up to the first parturition and following this another series was taken under reasonably uniform conditions. The 42 animals used in the experiment in which the liberal ration was compared with the light were measured monthly from the time they were one month old until cessation of growth occurred.

The following is a list of the measurements taken:

1. Height at withers
2. Height at a point between the hips

3. Height at hip points
4. Depth of chest just behind "elbow" joint
5. Width of chest just behind "elbow" joint
6. Width of hips (hip points)
7. Width of loin (center)
8. Length from poll to point of muzzle
9. Width of forehead
10. Circumference of muzzle at opening of mouth
11. Length from base of horns to withers
12. From highest point of withers to a line between hips
13. From a line between hips to tail
14. From point of shoulder to point of hips
15. From point of shoulder to ischium
16. From point of hip to ischium
17. From point of hips directly forward to last rib (To point at angle between loin and rib)
18. Heart girth just behind elbow joint
19. Girth of paunch at end of last rib
20. Smallest circumference of shin bone of foreleg
21. Smallest circumference of shin bone of hind leg

As a result of some study given this enormous accumulation of data, it was decided that only a few of the measurements taken are of any special significance. It was further decided that the growth of the animal, as far as the skeleton is concerned, can be determined reasonably well by a few measurements, and sufficiently well for most purposes, by one measurement alone. The one selected was height at withers.

As a result of this decision in our more recent studies of growth the skeletal measurements have been limited to that of height at withers. In taking this measurement it was observed by Regan[11] that fluctuations occurred which were too large to be considered as errors. At times an animal would measure two or three centimeters lower than the previous month. Regan found that the chief cause for this fluctuation was that the animal being measured, when allowed to stand for a short interval, gradually decreased in height. The backbone was observed to sink from a position above the shoulder blades until it was often below the level of the top of the shoulder blade. This is apparently the result of relaxation and stretching of the muscles. So long as the animal is in motion these muscles are tense and hold the body at a higher point, but as soon as the animal is quiet these muscles relax and the body settles appreciably. The animal upon moving again assumes its full height. To avoid this error the plan of measuring each animal three times in succession was adopted, and the animal was moved about between the times of taking the readings. The readings were also made as quickly as possible after the animal came to a rest.

THE METHOD OF MEASURING GROWTH

Until comparatively recent times the growth of animals has been measured almost entirely by means of their body weight. It is now recognized that this is not a satisfactory way to measure growth, because body weight and skeletal growth are, to a considerable degree, independent of each other. Apparently the "growth tendency" applies much stronger to the skeleton than to the tissues of the body. As already stated, Waters found it possible for an animal to grow in height and remain at constant weight for extended periods of time, or in extreme cases, even to make skeletal growth while losing in weight. The animal body seems to act as a storehouse. The growth of the skeleton continues to a certain extent, whether the tissues are storing up energy during a period of liberal feeding, or whether they are giving up energy as the result of a low plane of nutrition. An illustration of the greater effect of feed on weight than on skeletal growth is shown in Tables 1 and 2. These tables show a comparison for groups of animals of the effect of the ration upon growth of skeleton, and upon increase in body weight. The values given represent the weight and height in percentage of the normal for animals of the same age.

TABLE 1.—WEIGHT IN POUNDS IN PERCENTAGE OF THE NORMAL

Age months	Jerseys		Holsteins	
	Light-fed	Heavy-fed	Light-fed	Heavy-fed
6	95	99	85	120
12	80	104	73	118
18	83	128	84	130
24	84	109	88	119

TABLE 2.—HEIGHT AT WITHERS IN PERCENTAGE OF THE NORMAL

Age months	Jerseys		Holsteins	
	Light-fed	Heavy-fed	Light-fed	Heavy fed
6	98	99	96	102
12	95	101	93	103
18	95	102	95	103
24	96	101	97	103

It will be noted in examining the foregoing tables that the greatest difference in percentages of gains in weight occurred with Jerseys between 12 and 18 months old. At this time it amounted to 45 per cent. The greatest corresponding difference in percentage increase in height at withers occurred at the same age and amounted to only 7 per cent. An examination of figures for Holsteins shows similar results. The greatest difference in weight percentages was 46, while the difference in height at withers for the same period was only 8. The greatest difference in this entire group of Holsteins occurred with animals between 6 and 12 months old when it amounted to 10 per cent.

The weight of an animal certainly cannot be used alone as a fair measure of growth when the weight in relation to the growth of the skeleton can so readily be made to fluctuate between such wide limits. Attempts have been made to find a way to represent growth by a single term but as yet no satisfactory method has been devised. It seems necessary to represent the growth of body tissue in one term, and that of the skeleton by another. So far, no more satisfactory method than weight has been suggested for measuring increase in body tissue, and the skeletal growth by means of certain measurements.

If it is assumed that skeletal measurements in addition to weights, are essential in measuring growth, then the question at once arises which of the many possible measurements shall be used. Can any one measurement be used as an index to the growth of an animal? In several recent investigations the height at withers has been used to represent the skeletal growth. Is it satisfactory to base conclusions on any one measurement? With the idea in mind of answering these questions, a portion of the large amount of data on measurements were selected in such a way that the different dimensions of the body were represented, and these were studied to see if any correlation could be found.

In considering the skeletal growth of an animal the height first attracts attention. Among the different measurements taken on the experimental animals were two of height, one at the highest point of the withers (A) and the other at the hip-points (G). (Fig. 1).

The circumference of the body seemed best represented by the measurement taken at the heart girth (E-F), while the width between hip-points was chosen to represent the width development of the posterior part of the body. The third dimension, length, might be represented by a number of different measurements but the one chosen for this purpose was that which represented the distance from the point of shoulder to the point of ischium (C-D).

When these five measurements which seem to represent fairly well the dimensions of the body were decided upon, the next problem was to select the animals to be used as a source of the data. Since the measurements were complete from birth for only a part of the heifers, it seemed best to limit the preliminary study to sixteen representative animals four of which were included in each of the following groups:—

(a) Heavy-fed Jerseys (c) Heavy-fed Holsteins
(b) Light-fed Jerseys (d) Light-fed Holsteins

Since the study was of a preliminary nature only, the values were not plotted for every month but only for the first, second, third, sixth, ninth, twelfth, eighteenth, twenty-fourth, thirtieth, thirty-sixth, forty-eight, and sixtieth months. The relatively rapid growth at an early age was the reason for the short intervals between the plottings at the beginning.

Three or more methods may be used to represent growth in a tabular or graphical form. The first method is to plot the values of the measurements taken directly in centimeters. A curve plotted by this plan shows the size of the animal at any age and indicates at which points growth takes place. Such a method is satisfactory in comparing the relative increases of corresponding measurements of animals under different conditions. This method, however, cannot be used in comparing the relative increases of the different parts of the body, because it would involve comparing measurements of small value, such as increase in width at hips, with those of large value, such as the increase in heart-girth or the length of the animal. The only satisfactory way to compare the relative growth of the body parts seems to be by some percentage basis.

The second method is to calculate the amount of the increase at each point over the original measurement. By this method, if the animal or group of animals, was found to measure 70 centimeters as an average, at the beginning of the experiment and 84 centimeters at the next calculation, the increase would be 14 centimeters which amounts to 20 per cent. If the next measurement should be 91 centimeters the increase over 70 centimeters would be 21 centimeters or 30 per cent. In each case the percentage increase is based upon the original or beginning measurement. The method shows in a tabular or graphical form the amount of growth in terms of percent-

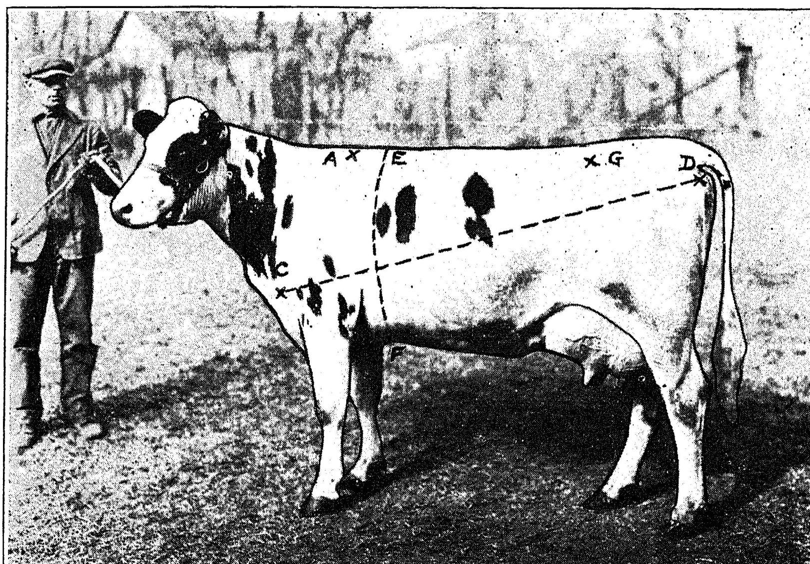

FIG. 1.—The points of anatomy used in making measurements to determine skeletal growth: A, Withers; C, point of shoulder; D, ischium; E - F, heart girth; G, hip points

ages of the first measurement. This method of representing growth is illustrated in Fig. 2.

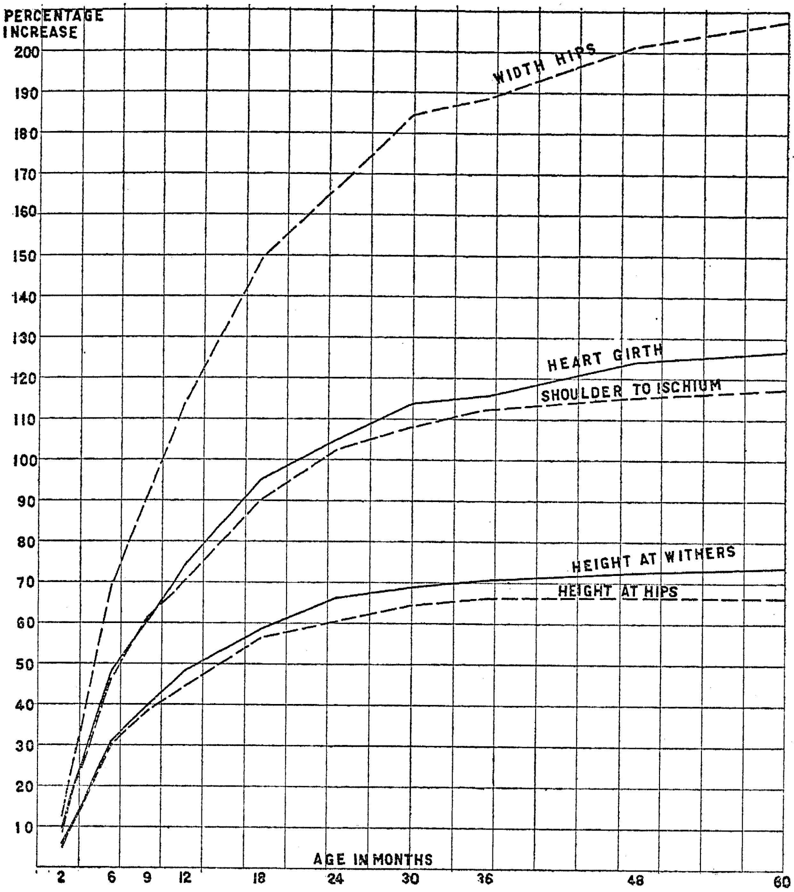

FIG. 2.—Growth of the body as represented by five different measurements and expressed in percentages. The figure is based upon the percentage increase of the measurements used over the first measurement taken at the age of one month. The height of the animal never doubles from one month of age to maturity, while the heart girth and length more than double and the width of hips more than triples during the same period. (Table 3)

The third plan is to consider the rate rather than the amount of growth by calculating the increase made in each period over the preceding value, and expressing the result in per cent. As an example of the method, the first value may be assumed to be 70 centimeters and the second 84 centimeters. In this case the increase is 14 centimeters or 20 per cent, as by the first method. But now suppose the next value is 91 centimeters. Here the gain for the period is only 7 centimeters and expressed in terms of per cent is only 8.3 per cent of 84. This gives a downward instead of an upward curve. By this method each increase is taken as a unit, and the percentage is based upon the preceding measurement. The rate is wholly dependent upon the size of the animal at the time and diminishes rapidly as the size of the animal increases. The second and third methods of representing growth are illustrated in Fig. 3.

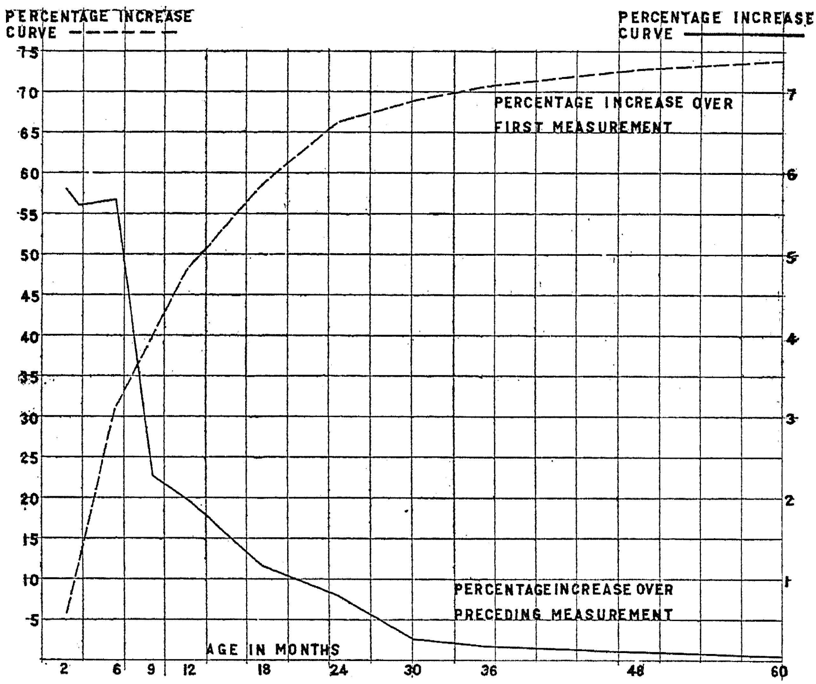

FIG. 3.—Two ways of representing growth. This figure is based upon measurements of height at withers. The solid line represents the percentage increase during each period over the preceding measurement. The broken line represents the percentage increase during each period over the measurement taken at the age of one month. The maximum percentage increase by the first method is 5.8. In the second method it is 73.9. The data from these two methods when plotted appear in the form of reversed curves

These two methods at first seem contradictory because when expressed graphically they give reversed curves. A more careful consideration, however, shows that they are consistent.

The method which represents the amount of growth is based on the average measurements of the 16 animals when one month old.

The point which represents maturity was set at 60 months. The amounts of increase of body parts in terms of per cent from the time the heifers were one month old to maturity was found to be as follows:

Height at withers	73.9 per cent
Height at hip-points	66.3 per cent
Length (shoulder to ischium).....	117.3 per cent
Heart girth	126.9 per cent
Width at hip-points	207.2 per cent

These values are shown in Table 3 and Fig. 2.

TABLE 3.—AMOUNT INCREASE OVER FIRST MEASUREMENT IN PER CENT

Age months	Height at withers	Height at hips	Point of shoulder to ischium	Heart girth	Width of hips
1	...	...	....	....	....
2	5.8	5.0	8.8	9.6	12.5
3	11.8	11.8	20.0	20.1	28.0
6	31.0	30.4	46.4	48.8	69.6
9	40.0	38.6	61.9	61.0	92.9
12	48.3	44.5	70.8	74.9	114.3
18	58.6	56.4	90.1	95.1	149.4
24	66.2	60.5	102.7	104.9	166.6
30	68.9	64.3	108.0	113.7	184.5
36	70.7	66.1	112.5	115.7	188.7
48	72.8	66.5	115.4	124.0	201.2
60	73.9	66.3	117.3	126.9	207.2

The most striking thing about these figures is that the animal never doubles its height. It seems almost impossible that a calf one month old is considerably more than half as tall as the mature cow. This fact is especially striking when the cow and calf are seen together. Check measurements, however, bear out the figures derived in the preliminary study.

The first impression from a glance at these figures is that one measurement cannot be used to represent the general body growth and that surely, when an animal never doubles its height, when it more than doubles its circumference, and when it more than triples its width, the growth of the different parts of the body is all out of proportion. A more complete study of the situation, however, shows that while one part of the body may double and another part, triple itself, the relation of the growth of one part to another is very nearly constant at all ages.

TABLE 4.—RELATIVE AMOUNTS OF PERCENTAGE INCREASE OF DIFFERENT BODY PARTS

Age months	Height at withers	Height at hips	Length shoulder to ischium	Heart girth	Width of hips
2	1.000	.862	1.517	1.655	2.155
6	1.000	.980	1.496	1.574	2.245
12	1.000	.921	1.466	1.551	2.366
24	1.000	.915	1.554	1.587	2.521
36	1.000	.935	1.591	1.636	2.668
48	1.000	.913	1.584	1.703	2.762
60	1.000	.897	1.587	1.717	2.803
Average	1.000	.917	1.542	1.632	2.503

This fact may be seen in Table 4 which was derived by dividing the percentages of increase for the different measurements by the value for the height at withers. The increase in height at withers is used as the basis of comparison and is given a value of 1. All other measurements are compared to it in the form of a ratio. For each 1 per cent increase in height at withers up to two months the height at hips shows a gain of .862 per cent and the length of the body 1.517 per cent. The uniformity of the relation between the different measurements at all ages indicates that the increase of the different body parts expressed in percentage continues in much the same proportion thruout the growing period. It will be noticed that there is a tendency for the values for the heart girth and width of hips to increase with age. This increase in value for heart girth can be easily explained by the observed fact that flesh deposition continues to a large extent after the growth of the skeleton ceases. Flesh deposition takes place presumably at all points around the circumference of the animal which results in a considerable increase in this measurement. It is a commonly observed fact that the hips seem to broaden rather rapidly in the more mature animal; so the ratio for the increase in the width of hips tends to widen. The reason for the relatively greater increase in width of hips over other parts of the body has never been satisfactorily explained. Taking all the data into account it is safe to say that the growth of the various parts of the body proceeds in rather definite ratios. The rapid increase in length comes at the same time as the rapid gain in height or circumference; so a measurement taken of the growth of one part of the body makes it possible to estimate closely the rapidity of growth and the time at which it occurs. The general conclusion seems justified from these considerations that any one of the fundamental measurements of the body may be used with a fair degree of accuracy as an index of skeletal growth.

Since the error in taking measurements which represent the height at withers seems to be as slight as any and to be affected to as small extent as any by varying conditions of the animal, this measurement has been chosen as a standard to represent skeletal development.

WEIGHT OF CALF AT BIRTH

The question is often raised as to the relation of the size of the calf at birth to the rate of growth and the size of the animal at maturity. The practical importance of this question is evident. An attempt was made to answer this question from a study of the data available from the University of Missouri dairy herd.

Table 5 shows data taken on heifers used in the experiment to determine the normal rate of growth for dairy animals. These heifers received what is considered a normal ration for an animal of the age and breed from birth to maturity. Both the Jerseys and Holsteins are divided into three groups, the first group includes those noticeably below the average in weight at birth, the second group those about normal, and the third group those above normal. While the number of animals supplying the data is unfortunately not as large as would be desirable, still if the factor involved is important enough to deserve much attention the results should be apparent. It happened with both breeds that the groups which were above and below normal at birth averaged higher at withers when 24 months old than the group which was of medium size at birth. The normal height at withers of a Holstein 24 months old is 126.5 centimeters and of a Jersey 120.4 centimeters. The data show that all five of the Holsteins below normal in weight at birth were normal or above at 24 months. Of the four approximately normal in weight at birth, all were below normal at 24 months; and of the six above normal at birth, four were above and two below normal at the same age.

Of the five Jerseys in the group below average at birth, only one was above normal at 24 months; of the four near normal weight

TABLE 5.—RELATION OF BIRTH WEIGHTS TO RATE OF GROWTH—ANIMALS ON NORMAL RATIONS

Cow No.	Weight at birth	Height at withers 6 mo.	Height at withers 12 mo.	Height at withers 18 mo.	Height at withers 24 mo.
	lbs.	cm.	cm.	cm.	cm.
Holstein Normal	89	100.9	114.0	121.8	126.5
235	75	....	....	....	126.5
238	81	....	112.0	121.5	128.0
243	85	104.7	112.6	123.3	128.0
239	85	....	114.0	123.0	131.5
Average	81	104.7	112.9	122.6	128.5
237	87	....	....	....	126.0
244	87	97.0	112.0	120.3	125.0
236	90	96.7	....	....	123.0
249	90	96.9	111.3	118.0	126.3
Average	89	96.9	111.7	119.2	125.1
241	92	102.0	115.5	120.5	126.8
245	95	101.0	111.5	119.3	123.5
248	97	99.3	113.5	119.8	126.0
246	102	102.0	114.8	123.5	128.1
251	110	104.2	119.3	124.5	133.0
Average	99	101.7	114.9	121.5	127.3
Jersey Normal	54	93.7	108.3	115.6	120.4
91	35	....	105.0	113.3	119.8
96	40	96.0	111.2	120.3	123.5
61	50	....	108.1	....	119.5
102	50	89.5	103.5	110.0	114.1
90	50	....	109.5	115.3	120.0
Average	45	92.7	107.3	114.7	119.3
98	55	97.0	110.5	117.7	120.0
100	55	90.7	107.0	113.8	119.3
101	57	94.0	109.5	115.8	118.4
Average	56	93.9	109.0	115.7	119.2
93	63	....	110.0	115.0	123.3
95	65	95.0	110.5	117.5	124.5
89	70	....	106.5	115.0	120.0
87	72	....	....	118.0	121.7
Average	68	95.0	109.0	116.6	122.3

at birth, all were below normal at 24 months; and in the group of four above normal at birth, three were above and one below normal at 24 months. These data possibly show a very slight tendency toward the animals larger at birth maintaining a lead over the normal during the period of most rapid growth, but individual variations are marked.

TABLE 6.—RELATION OF BIRTH WEIGHT TO MATURE HEIGHT AT WITHERS

Herd No. Cow	Birth weight	Height withers mature	Herd No. Cow	Birth weight	Height withers mature
	lbs.	cm.		lbs.	cm.
Normal	89	135.8		54	125.6
217	55	133.2	41	32	125.0
228	60	130.3	2	35	125.0
224	70	130.0	54	40	126.3
219	75	127.1	55	40	124.9
214	75	134.8	57	42	121.1
211	75	135.5	59	45	125.4
235	75	137.5			
Average	69	132.6	Average	39	124.6
231	90	132.0	39	50	120.0
227	80	132.9	13	50	123.4
221	85	140.9	22	30	119.7
237	87	134.9	50	52	128.1
222	90	130.6	58	55	125.0
223	90	134.4	8	55	124.3
213	94	134.0	14	55	119.0
			64	56	131.0
Average	88	134.2	Average	52.9	123.8
210	100	139.0	56	60	126.5
226	100	130.3	53	60	135.8
216	102	135.3	23	62	126.1
208	105	142.2	11	67	122.1
215	112	137.5	17	67	125.3
Average	103.8	136.8	Average	63.2	127.1

Table 6 gives the birth weight and height at withers at maturity for groups of Holsteins and Jerseys taken from data available for the University of Missouri herd, and which are not included in that data which represents the normal growth determination. The first group includes the animals smallest at birth of those which supply our data. No animal known to have been born prematurely is included. It will be noted in this table that there appears to be more relation between size at birth and size at maturity, and with the Holsteins the groups at maturity rank in size in the same order as at birth. In the case of the Jerseys, those largest at birth were also the largest at maturity, but those smallest at maturity were on the average with the group medium sized at birth.

TABLE 7.—A STUDY OF INDIVIDUAL BIRTH WEIGHTS

Age	Cow	Weight	Height	Cow	Weight	Height
months		lbs.	cm.		lbs.	cm.
Birth	2	35	....	17	67	....
1		72	71.1		87	75.0
2		98	75.0		117	80.8
3		130	79.7		151	85.5
6		288	95.1		282	98.0
12		572	112.5		472	112.5
18		852	119.8		705	118.3
27		748	123.8		637	122.0
33		707	124.8		792	124.2
46		935	125.0		815	125.8
60		...	125.0		....	125.5
Birth	41	32	....	53	60	....
19		747	119.0		785	121.6
20		...	119.0		....	125.0
28		962	122.5		1055	132.0
34		1031	123.5		1110	135.0
48		870	125.8		1122	135.3
54		851	125.3		1185	135.5
60		...	124.0		....	134.8
Birth	48	55	....	59	55	....
19		538	111.5		463	113.0
24		505	113.0		620	119.0
30		575	115.5		657	122.0
42		657	118.0		740	124.8
50		690	119.8		849	126.5
56		724	....		....	....
60		...	119.3		....	125.5

Table 7 gives records in detail for six animals selected to illustrate that, in individual cases at least, there is no definite relation between the birth weight and the final size. Cows 2 and 41 were only 65 per cent of normal size at birth but at maturity were practically normal sized animals and were decidedly larger than Cow 48 which weighed 105 per cent of normal at birth. Cow 17 was 126 per cent of normal at birth but was the same size at maturity as Cow 2 which was only 65 per cent normal at birth. Cow 53 was 115 per cent normal at birth and at maturity was 106 per cent of normal height. Cow 59 was practically normal in birth weight, also in height at maturity. Cow 2 weighing 35 pounds at birth was practically the same size when mature as Cow 67 which weighed nearly twice as much at birth. On the other hand, Cow 41 weighing 32 pounds at birth, altho she attained nearly normal size when mature, was far behind Cow 53 which had a weight nearly twice as great at birth. Cows 48 and 59 starting at the same birth weight showed a marked difference in size at maturity.

The data in Table 7 indicate that the size at birth does not necessarily, in individual cases, bear any relation to the rate of growth or size at maturity.

When the data as a whole are considered, there is little evidence of a relationship between the size of animals at birth and at maturity. The most that can be said is that generally there seems to be a slight tendency in that direction, but individuals show such wide variations that little practical importance should be attached to this point.

BREED AS A FACTOR IN GROWTH

Many characteristics of great interest to the breeder and of wide practical importance are typical of certain breeds and are so closely involved with the hereditary factors of the breed as to be transmitted with reasonable certainty. For this reason it is of interest to examine the data on growth to determine to what extent breed is involved as a factor. Data covering this point are given in Table 8. These data are based upon measurements and weights that have been taken during the investigation already described which concerns the normal rate of growth of dairy animals. Altho incomplete, sufficient data are already at hand to make possible a fairly accurate statement of the influence of breed on the rate of growth and time of maturity. The data are taken from purebred animals kept under what is considered normal conditions. The height measurements were taken monthly until the rate of growth became very small and from then on at longer intervals. The Jerseys were measured monthly until 24 months old, after this when they were 27, 30, 33, 36, 42, 48 and 50 months old. The measurements were continued monthly for

TABLE 8.—NORMAL GROWTH OF THE JERSEY AND HOLSTEIN BREED IN HEIGHT AND WEIGHT

Age	Height		Weight	
	Jerseys	Holsteins	Jerseys	Holsteins
Month	cm.	cm.	lbs.	lbs.
Birth	66.1	71.8	53	90
1	70.3	76.8	76	121
2	74.7	82.0	105	157
3	79.3	86.8	140	200
4	83.9	92.0	174	249
5	89.3	96.5	222	302
6	93.7	100.9	266	349
7	96.8	104.0	302	389
8	99.8	107.1	340	425
9	102.8	109.1	376	466
10	105.0	111.3	407	501
11	106.5	112.6	432	529
12	108.3	114.0	456	558
13	110.1	115.7	480	574
14	111.4	117.4	503	596
15	112.7	118.8	528	612
16	113.4	120.3	533	643
17	114.6	121.3	553	660
18	115.6	121.8	572	686
19	116.8	122.7	598	715
20	117.5	123.8	621	747
21	117.9	123.9	649	774
22	119.1	124.9	668	796
23	119.8	125.7	689	824
24	120.4	126.5	716	841
25	....	127.6	737	869
26	....	128.2	...	893
27	121.9	129.3	...	927
28	....	129.8	...	...
29	....	130.5	765	...
30	122.9	130.7	...	...
31	....	....	...	971
33	123.2	132.2	...	...
35	....	....	779	...
36	124.1	132.8	...	...
37	....	....	...	1055
42	124.4	133.5	...	...
44	....	....	870	1098
48	125.6	135.1	...	....
50	....	....	843	1132
54	....	135.8	...	....
57	....	....	904	....
58	....	....	...	1219
60	125.6	136.5	...	....
64	....	....	...	1207

the Holsteins until they were 30 months old and after that at the same intervals as for the Jerseys.

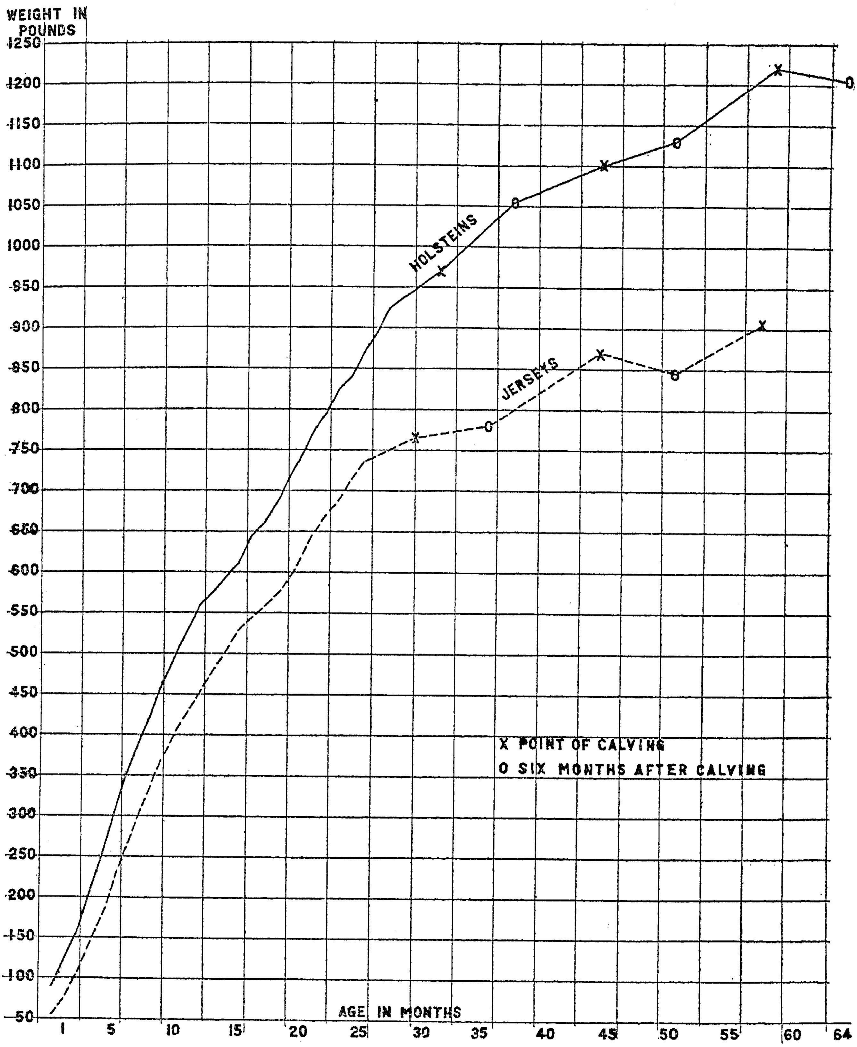

FIG. 4.—The relation of breed to growth as represented by weight. Holsteins normally make somewhat more rapid growth in weight from birth and grow for a much longer period than Jerseys. Their greater size at maturity is the result of a combination of these two factors. The growth in weight of cows in milk can be represented most satisfactorily by using weights taken immediately after calving and six months later. (Table 8)

The weights were taken under controlled conditions for three days in succession at the middle point of each month. It is an exceedingly difficult matter to obtain a fair series of weights representing the life of a cow on account of the extreme variations due to pregnancy and lactation. The weights were taken according to the plan already described in detail. They were taken monthly up to the time of calving and for three days in succession following parturition, and again six months later. For this reason the weights given in the table appear to come at irregular intervals after the animal has passed the second year. The average age at first freshen-

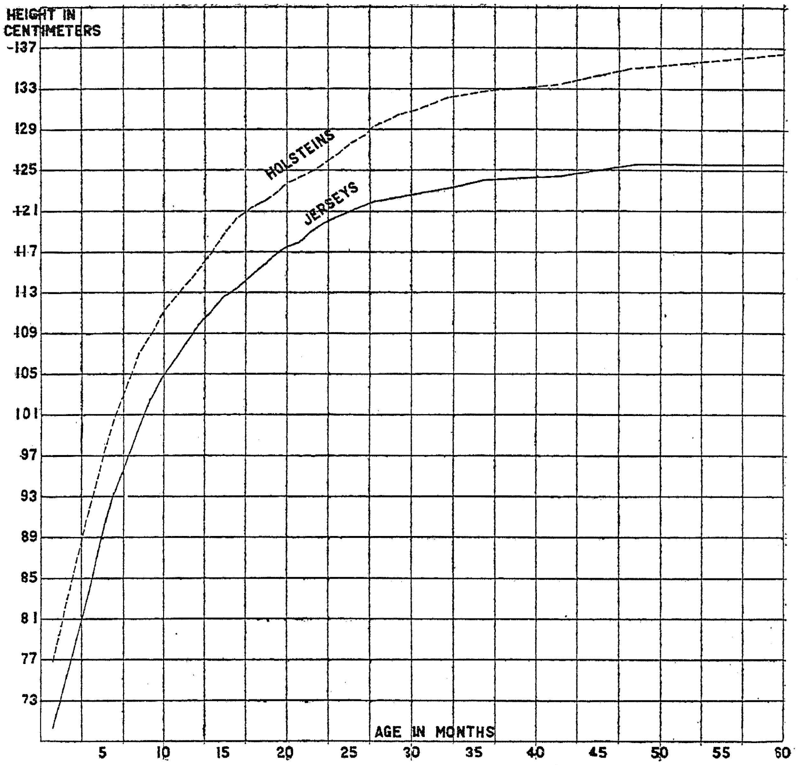

Fig. 5.—The relation of breed to skeletal growth. The difference in height between Jerseys and Holsteins at birth is 5.7 c.m. At the age of 24 months it is only 6.1 c. m. From this point the difference between them gradually increases. The greater size of Holsteins is due to a greater size at birth and to a prolonged period of growth. The amount of skeletal growth for Jerseys and Holsteins is almost exactly the same for the first two years. (Table 8)

ing of the Holstein group was 31 months and the average weight 971 pounds. Six months later the average weight was 1055 pounds. The average age at second calving was 44 months, the weight following calving 1098 pounds. The data are shown graphically in Figs. 4 and 5, and a summary which gives a comparison of the increase in height and weight for six-month periods is found in Table 9. The

TABLE 9.—COMPARISON OF NORMAL GAINS BY JERSEYS AND HOLSTEINS

	Jerseys		Holsteins	
	Increase in height	Gain in weight	Increase in height	Gain in weight
	cm.	lbs.	cm.	lbs.
Birth to 6 months.......	27.6	207	29.1	259
6 months to 12 months..	14.6	196	13.1	209
12 months to 18 months..	7.3	116	7.8	128
18 months to 24 months..	4.8	144	4.7	155
24 months to 36 months..	3.7	...	6.3	...
36 months to 48 months..	1.5	...	2.3	...
48 months to 60 months..	...	...	1.4	...

data show that the growth curve for the Jersey and Holstein breeds as indicated by height measurements is strikingly uniform until the animals are about 24 months old. There is a difference of 5.7 centimeters in height of the animals at birth and at 24 months old the difference is only 6.1 centimeters. From this point on the difference in height steadily increases because the Holstein animals continue to grow. Growth for this breed ceases at some point between 48 and 60 months, while that for the Jersey has practically ceased at four years. It has been generally recognized that the Holstein breed is slower in reaching maturity, but it has not been pointed out that the rate of growth is nearly the same for the two breeds during the first two years. From birth to 24 months the normal increase in height at withers for Jerseys is 54.3 centimeters and for Holsteins 54.7 centimeters. At 24 months the Jerseys have completed 91.2 per cent and the Holsteins 84.5 per cent of their total increase in height measurement. The greater size of skeleton of Holsteins at maturity as compared with Jerseys is not due to a greater rate of gain but to a greater size at birth and a more prolonged period of growth. In regard to weight, the Holsteins make somewhat greater gains from the first as seen in Table 8. At 24 months the Jerseys have reached 79 per cent and Holsteins 70 per cent of their mature weight. Animals of the Holstein breed also continue to increase in weight to an age beyond the point at which growth ceases with the Jerseys. On account of the great extremes in weight due to pregnancy and lactation it is very difficult to fix an age at which maximum weight is reached. It probably is not less than two years after the skeleton ceases to grow. Figure 13 shows typical weight curves for two groups of Jerseys from a point several months before the first freshening until after the third freshening for the early-calving group which averaged 22.7 months at first parturition, and until after the second parturition for the group which calved at an average age of 34.9 months. From Table 8 it appears that Jersey cows continued to increase in weight at least up to nearly six years of age. The data for the Holsteins do not extend far enough to make clear the limits of their increase in weight. Other data available show that the maximum weight is attained, usually when the animal is about seven years old. This increase in weight after the skeleton ceases to grow must be largely muscle and tissue. It is questionable if this gain can be attributed to an accumulation of fat, since the animals were maintained as nearly as possible in the same condition of flesh from year to year. In this respect the growth of cattle is similar to that of man. It is well known that weight in man does not reach the maximum until long after growth in stature has ceased.

Liberality of the ration.—It is a well-known fact that the rate of growth of an animal is dependent to a considerable extent upon the amount of nutrients received. Observing stockmen have long known that the time of maturity of an animal is hastened by liberal feeding and delayed by scant feeding. It is also a common, altho not universal, belief among stockmen that liberal feeding of the young animal results in a larger animal at maturity. Concerning this point probably the correct view is, that with sufficient feed it is possible for the animal to grow to the full extent of its inheritance, while insufficient feed may cause the animal never to reach the full development made possible by its inheritance. Data concerning the effect of the liberality of the ration are given in Tables 10 and 11. Full details concerning the rations given these animals are found in Bulletin 135 of the Missouri Experiment Station. It is sufficient to say here that the heavy-fed group received whole milk and practically all they would consume of a grain mixture composed of corn and oats, with alfalfa hay for roughage. The light-fed group received skim milk during the first six months and alfalfa hay, and in some cases pasture, but no grain up to the time of first calving. After calving both received the same ration which was the one fed to the milking cows in the herd.

There seems no doubt that all requirements of a ration for growth were met with both groups, and that the only difference of importance was in the total nutrients received.

TABLE 10.—INFLUENCE OF RATION UPON RATE OF GROWTH—HEIGHT AT WITHERS

Age	Holsteins		Jerseys	
	Heavy-fed	Light-fed	Heavy-fed	Light-fed
months	cm.	cm.	cm.	cm.
1	76.7	75.6	70.1	71.6
2	81.7	80.4	73.1	75.9
3	88.1	84.6	77.9	80.5
4	93.6	88.6	83.6	84.2
5	99.7	93.7	88.6	87.9
6	103.4	96.7	92.7	92.3
7	106.2	98.2	96.5	93.9
8	108.7	99.7	99.4	95.2
9	111.5	101.2	102.2	97.2
10	113.5	102.7	105.0	99.1
11	115.8	104.5	107.3	101.4
12	117.8	106.3	108.8	102.5
13	119.2	107.6	110.7	103.9
14	120.8	109.2	112.4	105.3
15	122.3	110.8	114.2	106.3
16	123.8	113.0	114.5	107.8
17	124.9	113.8	115.7	109.2
18	125.4	115.3	116.6	110.6
19	126.9	116.6	118.8	112.3
20	127.9	117.4	119.8	113.2
21	128.5	118.6	120.5	114.1
22	129.1	119.7	120.9	114.9
23	129.5	121.1	121.4	115.9
24	130.1	121.6	121.8	116.3
25	130.7	122.6	122.0	116.6
26	131.2	123.6	122.9	117.0
27	131.6	123.9	123.1	117.6
28	131.9	124.5	123.4	118.0
29	132.3	124.9	123.8	119.0
30	132.6	125.6	124.2	119.5
36	133.7	126.9	125.1	121.9
42	134.7	128.5	....	121.9
48	134.9	129.5	125.7	123.0
60	135.9	130.3	125.9	123.0

TABLE 11.—INFLUENCE OF RATION UPON RATE OF GROWTH—WEIGHT

Age	Holsteins		Jerseys	
	Heavy-fed	Light-fed	Heavy-fed	Light-fed
months	lbs.	lbs.	lbs.	lbs.
1	113	104	66	87
2	139	137	88	109
3	212	177	119	137
4	263	214	161	173
5	362	258	203	211
6	418	292	248	245
7	455	307	285	261
8	490	326	321	279
9	545	344	357	295
10	591	372	393	312
11	628	382	436	336
12	659	404	463	363
13	714	431	504	378
14	737	463	540	404
15	776	491	579	431
16	819	519	628	455
17	852	535	667	477
18	891	569	708	495
19	932	588	744	515
22	938	666	772	568
28	1036	745	842	664
34	1094	866	890	734
40	1070	883	884	743
46	1122	946	904	801
54	1119	968	907	822
54-66	1290	1065	937	880
66-78	1265	1113	975	851
78-90	1191	....	1006	922

The results given in Tables 10 and 11 are illustrated in Figs. 6 and 7. It is seen that the Holstein groups started at practically the same height at 1 month, and that the spread between the curves shows a sudden increase beginning at six months. This is clear with both the Jersey and Holstein groups and is to be attributed to the fact that milk was dropped from the ration at this point. The light-fed group from then on received roughage only until first parturition. As a result they did not consume a sufficient amount to supply nutrients equal to those received by the heavy-fed group which consumed a heavy grain ration during this period.

The difference in the height of the two groups increased gradually until the maximum was reached at 19 months for both the Jerseys and the Holsteins. From this point on the difference be-

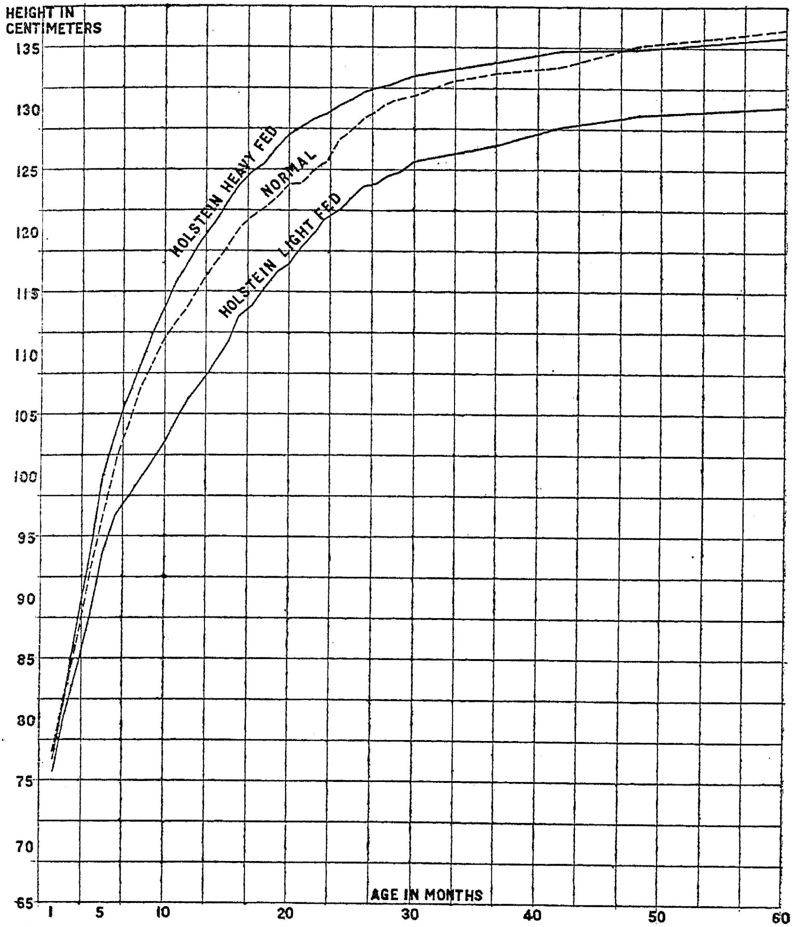

FIG. 6.—The liberality of the ration as a factor in determining the skeletal growth of Holsteins. Beginning at 6 months of age when milk feeding was stopped the light-fed group began to fall below the normal. At five years of age, when skeletal growth had ceased, they were still considerably undersized. The heavy-fed group were somewhat above normal in size, especially between the ages of 10 and 30 months. At 5 years of age when skeletal growth had ceased, they were practically normal. (Table 10)

comes less marked, which means that the light fed group continued growing over a somewhat longer period than was the case with the group which received the heavy ration. At no time, however, did the light-fed group in either the Holstein or Jersey breed reach the size of the heavier-fed group. At 60 months, when the Holsteins had reached maturity, so far as growth of skeleton is concerned, the heavy-fed group had an average height of 5.6 centimeters in excess of the light-fed group; while with the Jersey breed the difference was 2.0 centimeters.

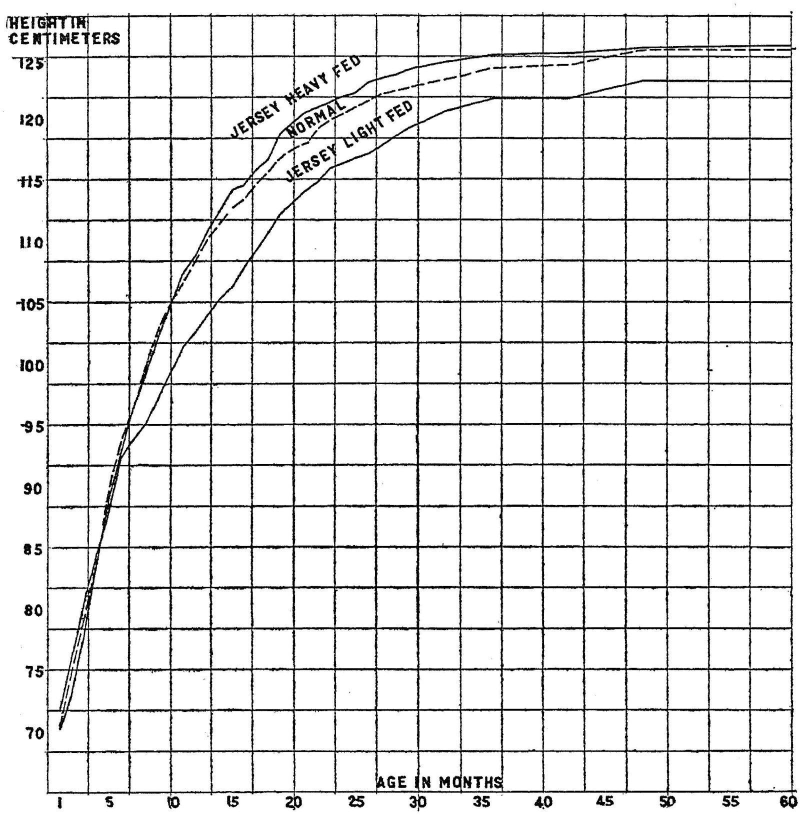

FIG. 7.—The liberality of the ration as a factor in determining the skeletal growth of Jerseys. Results with Jerseys are almost identical with those shown for Holsteins in Fig. 6. The light-fed group began to fall below normal when milk was taken from the ration at 6 months of age. At 5 years, nearly one year after skeletal growth had ceased, this group was 2.6 c. m. below the normal. The heavy-fed group passed the normal at 10 months and at maturity remained slightly above. (Table 10)

As shown in Figs. 6 and 7 the heavy-fed groups more nearly approached the normals for the breeds. In the case of the Holsteins the mature size was even slightly below the normal. It is clear from these figures that the light-fed groups, as a result of the feed which they received when young, never reached the normal size. This bears out the fact that the conditions of nutrition during growth may result in the size at maturity being below normal; and that high nutrition increases the rate of growth to a considerable extent, but cannot stimulate growth beyond the maximum inheritance of the animal. These results also illustrate the fact earlier mentioned that a very liberal ration shows a greater relative effect upon the increase in weight than on the skeleton growth. This fact is made clear in Table 12

TABLE 12.—COMPARISON OF EFFECT OF RATIONS UPON SKELETON GROWTH AND INCREASE IN WEIGHT IN PERCENTAGE OF THE NORMAL

	Jerseys		Holsteins	
	Light-fed	Heavy-fed	Light-fed	Heavy-fed
	Weight lbs.	Weight lbs.	Weight lbs.	Weight lbs.
6 months	95	99	85	120
12 months	80	104	73	118
18 months	83	128	84	130
24 months	84	109	88	119
	Height cm.	Height cm.	Height cm.	Height cm.
6 months	98	99	96	102
12 months	95	101	93	103
18 months	95	102	95	103
24 months	96	101	97	103

in which the data are expressed for the four groups in terms of percentage of the normal. At 18 months the light-fed Jerseys showed 83 per cent of normal growth in weight and 95 per cent in height and the Holsteins at the same age 84 per cent in weight and 95 per cent in height. The heavy-fed Jerseys at the same age were 128 per cent of normal in weight and 102 per cent in height, and the heavy-fed Holsteins were 130 per cent in weight and 103 per cent in height. These data show in general that a more liberal ration tends to materially increase the rate of gain, especially in weight, and as a result maturity is reached at an earlier age. The growth rate of the animals on the lighter ration is slower and somewhat prolonged, but the size at maturity is not equal to that attained by those which received a heavier ration. The earlier maturity of the animal is shown not alone by size but also by earlier sexual maturity, data on which has been given in the earlier publication.[12]

GESTATION

Investigations by one of us already published[13] show that the tax upon the cow in the way of nutrients necessary to develop the fetus is too small to be of any special significance from the standpoint of animal feeding. It was found that a ration which was just sufficient to maintain a cow at uniform weight when dry and farrow was also sufficient, if fed thruout the period of gestation, to maintain the cow at normal weight and to develop a normal fetus. The probable explanation of this result is the small amount of dry matter which the fetus contains. These data show that an average Jersey calf at birth, including amniotic fluids and placenta, contains only about 20 pounds of dry matter. It was pointed out that under abnormal conditions of feeding, gestation might prove to be a much more serious tax on the cow than was shown in investigations where, so far as present knowledge goes, the rations supplied everything needed for both growth and maintenance. The results of the investigations with growing heifers herein reported are consistent with those to which reference has already been made.[14] Practical breeders of dairy cattle, because of the supposed tax upon the animal involved by gestation, often emphasize strongly the value of liberal feeding of the pregnant animal. Practice has fully justified liberal feeding of the pregnant dairy cow. Its value, however, is not so much for the sake of the growing fetus, as is often assumed, but rather to insure that the cow herself will have the necessary reserve of nutrients and possibly of mineral matter, according to the investigations of Forbes, to enable heavy milk production to be sustained. The practical dairy cattle breeder has likewise over emphasized the influence of gestation upon the growth of heifers. Experienced breeders of dairy cattle know that a heifer calving at a very early age and once each year thereafter does not, as a rule, reach the same size as one which is more mature before the time of first freshening. The error commonly made is that of attributing the check in growth and failure to attain normal size at maturity to the strain of pregnancy, when properly it should be attributed to the strain of milk production. Data on the relation of gestation to growth are given in Tables 13, 14, 15 and 16.

TABLE 13.—INFLUENCE OF GESTATION ON GROWTH OF DAIRY HEIFERS

	Light-fed				Heavy-fed			
	Pregnant		Not pregnant		Pregnant		Not pregnant	
	height	weight	height	weight	height	weight	height	weight
Months from calving	cm.	lbs.	cm.	lbs.	cm.	lbs.	cm.	lbs.
Jerseys								
9	106.3[1]	432	108.2[2]	490	111.1[3]	484	109.5[4]	487
8	108.2	458	109.0	514	113.3	532	112.5	521
7	109.5	478	110.6	513	114.5	569	114.3	557
6	110.7	497	112.1	515	116.0	614	115.5	599
5	111.2	525	113.5	538	117.7	658	116.9	633
4	112.6	544	114.0	561	118.4	666	117.3	670
3	113.7	566	115.7	576	118.7	716	117.9	696
2	114.3	582	117.0	592	119.5	753	118.7	721
1	115.1	606	117.3	616	120.2	787	119.7	724
1[9]	115.3	556	117.2	619	120.1	737	119.9	747
Holsteins								
9	....	608[5]	....	564[6]	118.9[7]	707	119.3[8]	696
8	....	667	....	572	120.5	734	120.3	747
7	....	699	....	585	121.6	784	122.1	770
6	....	760	....	626	122.7	814	123.5	816
5	....	786	....	644	124.5	854	124.3	852
4	....	803	....	682	125.4	889	125.4	884
3	....	826	....	709	126.0	931	126.6	928
2	....	863	....	725	126.8	970	128.0	973
1	....	890	....	743	127.9	1021	128.9	1009
1[9]	....	820	....	748	128.1	882	129.8	1020

1. Average for six animals.
2. Average for four animals.
3. Average for three animals.
4. Average for five animals.
5. Average for two animals, the height measurements are incomplete.
6. Average for five animals.
7. Average for four animals.
8. Average for four animals.
9. Immediately following parturition for pregnant group and at same age for non-pregnant group.

TABLE 14.—COMPARISON OF GAINS IN HEIGHT AND WEIGHT PREGNANT AND NON-PREGNANT HEIFERS DURING GESTATION PERIOD OF PREGNANT GROUP

	Increase in height	Gain, weights one month before calving	Gain, weights after calving	Gain, weights after calving plus weight of calf
	cm.	lbs.	lbs.	lbs.
Jerseys light-fed				
Pregnant ...	8.8	174	124	168
Check group not pregnant...	9.1	126	129	129
Jerseys heavy-fed				
Pregnant ...	9.1	303	253	291
Check group Not pregnant...	10.2	237	260	260
Holsteins light-fed				
Pregnant ...	...	282	212	280
Check group not pregnant...	...	179	184	184
Holsteins heavy-fed				
Pregnant ...	9.0	314	175	253
Check group not pregnant...	9.6	313	324	324

TABLE 15.—INFLUENCE OF GESTATION UPON GROWTH—JERSEY HEIFERS ON NORMAL RATIONS

Age	Four heifers average age at calving 26 months		Four heifers average age at calving 35 months	
	Height	Weight	Height	Weight
Months	cm.	lbs.	cm.	lbs.
17	114.6	554	115.1	564
18	117.7	583	117.2	610
19	116.9	615	117.6	618
20	117.3	646	117.7	637
21	118.3	669	118.1	644
22	119.2	691	120.0	674
23	119.5	727	120.6	686
24	119.8	757	121.1	719
25	120.2	791	121.5	716
26	120.6	824	121.8	733
Weight after calving	....	729	....	...

TABLE 16.—INFLUENCE OF GESTATION UPON GROWTH—MEASURED BY HEART GIRTH AND WIDTH OF HIPS

Months previous to parturition	Average heart girth		Average width at hips	
Pregnant group	Ten pregnant heifers	Ten non-pregnant heifers	Ten pregnant heifers	Ten non-pregnant heifers
	cm.	cm.	cm.	cm.
8	142.6	142.6	38.0	37.5
7	145.2	145.4	39.3	38.2
6	148.0	148.2	40.3	39.1
5	151.2	150.6	41.1	40.0
4	152.8	153.6	41.6	40.8
3	154.8	155.2	42.5	41.6
2	156.4	157.7	43.1	42.6
1	158.4	160.7	44.1	43.8
0	161.5	163.5	44.7	44.6

Table 13 gives the data for height at withers and weight for Holsteins and Jerseys which received both heavy and light rations up to calving time. As stated in a previous paragraph, one group of animals received a heavy and the other a light ration up to calving. These were sub-divided into two groups with reference to age at first calving. One-half of each main group were bred to calve when 20 to 24 months old, and the remainder when 30 to 36 months old. The comparisons made in Table 13 are between the pregnant animals and the non-pregnant animals which received the same ration and which were the same age. Figs. 8 and 9 combine the data from the heavy and light-fed groups. Table 14 gives a summary of the data in a form which is more readily studied. The height figures seem to show a slight tendency for gestation to check growth. The light-fed Jerseys, for example, showed an average growth of 8.8 centimeters for the pregnant group and 9.1 centimeters for the open group. In each of the three comparisons, slightly greater growth was made by the open group.

Weights taken on pregnant animals one month before parturition in every case were higher than those for the non-pregnant animals. If the weights of the pregnant group taken immediately after parturition are compared with the open group the advantage is with the latter. If the weights of calves born are added to that of the cows taken following parturition, then in three out of four comparisons the combined figure exceeds that of the open group.

Table 15 shows data taken on an entirely different group of animals, those used in the investigations to determine normal growth, reference to which was made in the paragraph concerning source of data. It was possible to select data from four animals that calved

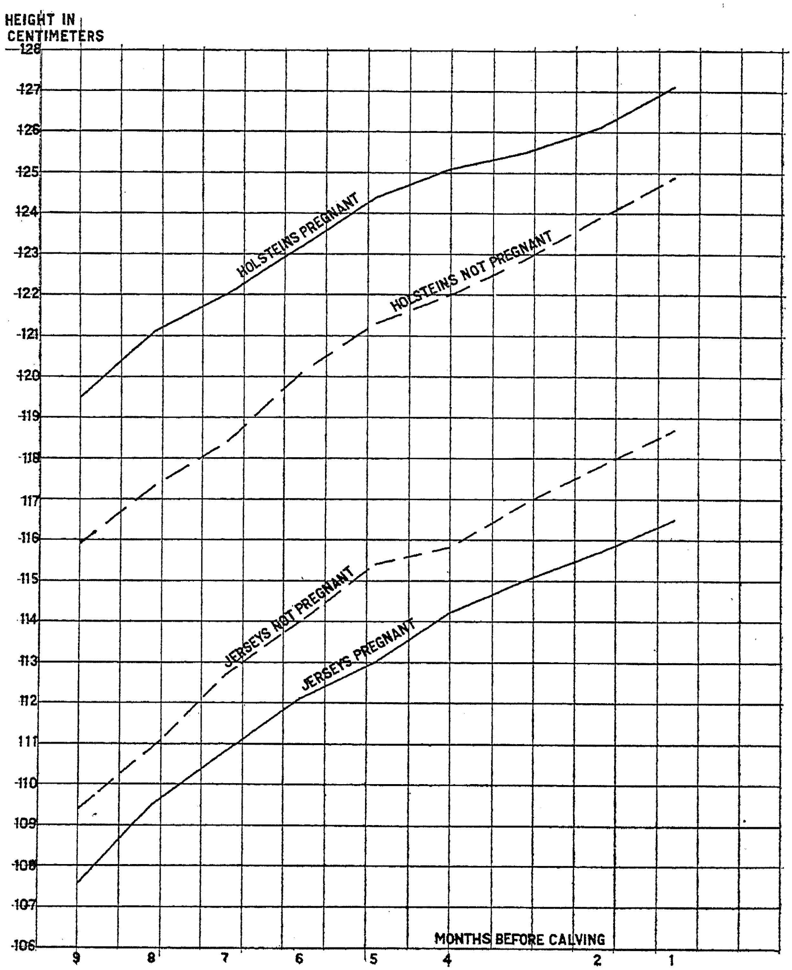

FIG. 8.—The influence of gestation upon skeletal growth. Pregnancy has very little effect upon the skeletal growth of dairy animals. Figure 8 is a combination of values given in Table 13 for heavy- and light-fed Holsteins and heavy- and light-fed Jerseys

at an average age of 26 months for comparison with that from an equal number calving at an average age of 35 months. The data show that the pregnant animals gained 6 centimeters in height during the period of gestation, and the open group 6.7 centimeters dur-

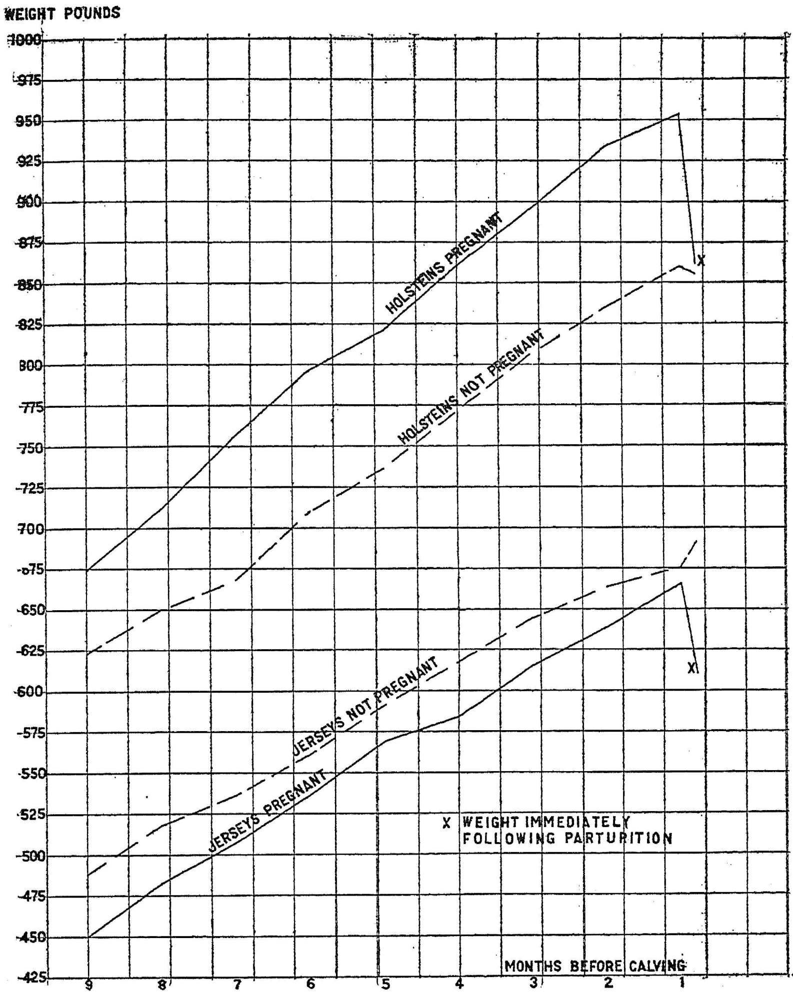

FIG. 9.—The influence of gestation upon weight. Pregnancy has a very little effect upon the actual growth of dairy animals. Figure 9 is a combination of values given in Table 13, for heavy- and light-fed Holsteins and heavy- and light-fed Jerseys

ing the same length of time at the same age. Altho the pregnant group lost 95 pounds as a result of parturition, the total gain by this group from the time of breeding until after parturition was still greater than that of the open group during the same period. These data are entirely consistent with those given in Table 13.

Table 16 gives the average increase in heart girth and width at hip of a group of ten heifers during gestation, and of the same number of open heifers of the same age and on the same ration. The animals are the same ones which supply the data in Table 13. During the nine months the pregnant animals increased 18.9 centimeters in heart girth and the open heifers 20.9 centimeters. In width of hip, the pregnant group increased 6.7 centimeters and the open group 7.1 centimeters. The results apparently show, as does Table 13, a slight check on skeleton growth due to gestation. However, the check is so small that it could not be observed at all and only shows up when accurate measurements are made.

The general conclusion from the data given is that gestation does exert a measureable effect upon skeleton growth of dairy heifers, but the check is so slight that for all practical purposes it may be entirely ignored. If the growth of the animal is measured by weight, no check is found which is due to gestation. Pregnant animals shortly before parturition will outweigh open animals of the same age which have received the same ration. Weights taken following parturition show little difference between groups which have developed the fetus and the open groups of the same age.

THE INFLUENCE OF LACTATION UPON GROWTH

Aside from the character of the ration, gestation and lactation are the most important factors to be considered in connection with growth. As indicated, gestation is a factor of little importance in this connection, due probably to the very small tax upon the animal which results from the development of the fetus. However, as soon as lactation begins the situation is different.

Table 17 gives data taken from the investigations concerning the growth and development of dairy heifers to which reference has already been made. One group was bred to calve at an early age, 20 to 24 months, and the other group at what would be called a late age, 30 to 36 months.

The figures given in Table 17 represent the height and weight of the animals in milk as compared with the group not in milk but of the same breed and consuming the same ration as that received by the group in milk before freshening.

The weights given after calving for the group not in milk are those following the first parturition for this group; but because the first calving by this group did not come at an age exactly comparable with the second calving of the first group, it is not possible to give a complete set of weights for the group not in milk. The weights given are for comparable ages. The data in this table concerning growth in height are given graphically in Figs. 10 and 11.

TABLE 17.—INFLUENCE OF LACTATION UPON GROWTH OF DAIRY HEIFERS

	Group 1 Heifers in milk		Group 2 Heifers not in Milk	
	Height at withers	Weights	Height at withers	Weights
Jerseys light-fed	cm.	lbs.	cm.	lbs.
Month before calving (Group 1)	115.1	606	117.3	616
Month after calving (Group 1)	115.3	556	117.2	619
	114.8	554	118.8	656
	115.5	569	119.3	700
	116.3	586	119.9	746
	116.6	593	121.1	...
	117.0	619	122.1	...
	117.8	626	122.9	...
	118.4	646	122.5	...
	118.9	665	122.8	...
	119.2	684	123.0	...
	119.5	706	123.5	...
Month before 2nd calving (Group 1) 1st calving (2nd Group)....	120.3	730	123.9	...
After calving	120.3	686	124.1	805
Jerseys heavy fed				
Month before calving (Group 1)	120.2	787	119.7	724
Month after calving (Group 1)	120.1	737	119.9	747
	120.2	726	120.5	782
	120.5	704	121.8	808
	121.7	706	122.1	824
	121.8	700	123.0	847
	122.3	702	123.1	852
	122.5	720	123.7	882
	122.8	734	124.1	886
	123.8	766	124.6	...
	123.5	747	124.5	...
	124.2	798	124.7	...
Month before 2nd calving (Group 1) First calving (Group 2)....	124.0	828	125.0	...
Month after calving	124.0	741	125.8	981
Holsteins heavy-fed				
Month before calving (Group 1)	127.9	1021	128.9	1009
Month after calving (Group 1)	128.1	882	129.8	1027
	128.3	905	130.1	1058
	128.7	883	130.6	1109
	128.9	897	131.9	1134
	129.4	883	132.5	1162
	129.9	869	132.8	1179
	129.9	902	133.0	....
	130.6	921	134.0	....
	131.3	955	134.1	....
	131.4	988	134.2	....
	131.5	1023	134.4	....
Month before 2nd calving (Group 1) 1st calving (Group 2)......	131.8	1052	134.8	....
After calving	131.8	961	135.0	1225

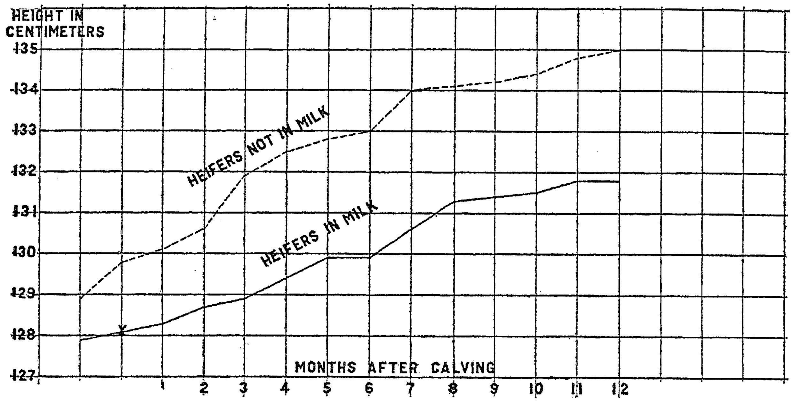

FIG. 10.—The influence of lactation upon skeletal growth. These data represent a group of heavy-fed Holsteins. One month before calving the non-pregnant group averaged 1 c.m. taller than the pregnant group. Twelve months after the calving of the pregnant group the late calving group was on the average 3.2 c.m. taller. In contrast to pregnancy, lactation exerts a strong influence upon growth. (Table 17)

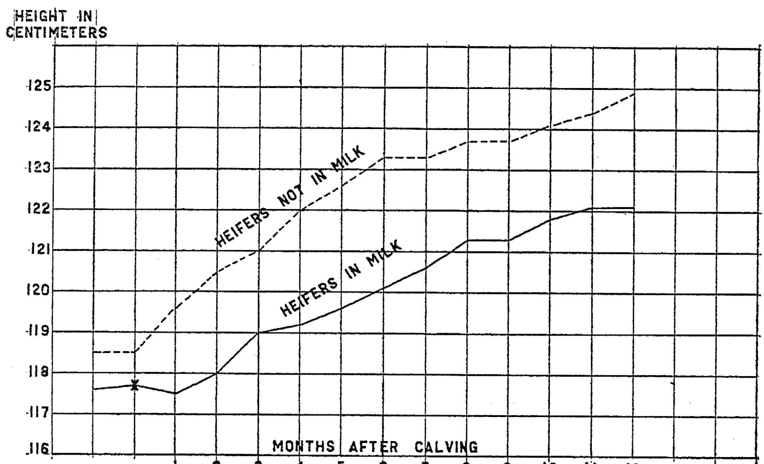

FIG. 11.—The influence of lactation upon skeletal growth. This figure is based upon combined data for groups of heavy- and light-fed Jerseys. The results are almost identical with those for Holsteins given in Figure 10. (Table 17)

These data show clearly that the skeleton growth is considerably checked by lactation. The light-fed Jersey group, for example, shows a growth of 5.2 centimeters in height at withers and the group not in milk 6.8 centimeters. The group of Jerseys which received the heavy ration previous to calving made a growth of 3.8 centimeters in height during the lactation period, while those of the group not in milk gained 6.1 centimeters.

The difference in the gains in weight are even more significant, as would be expected. The Jersey group which calved early weighed 606 pounds before first calving and the group which calved late weighed 616 pounds. The group in milk weighed 686 pounds after the second calving, a gain of only 80 pounds. The group which calved late weighed 616 pounds at the time the early calving group freshened the first time, and weighed 805 pounds after calving, which makes a gain of 189 pounds as compared to a gain of 86 by the group in milk.

This group which received the heavy ration up to first calving actually weighed 46 pounds less after the second calving than before the first, while the heavy-fed group not in milk during the period gained 257 pounds. Similar results are found for the Holsteins.

Tables 18 and 19 give data regarding the influence of the age at first calving upon the growth of the animal, not only during the

TABLE 18.—INFLUENCE OF AGE AT FIRST CALVING ON GROWTH

Age	Light-fed Jerseys		Heavy-fed Jerseys	
	Early calving seven animals	Late calving five animals	Early calving four animals	Late calving five animals
Months	Height cm.	Height cm.	Height cm.	Height cm.
19	111.1	113.6	119.5	118.1
20	112.2	114.3	120.5	119.1
21	112.4	115.8	120.7	120.3
22	113.4	116.4	121.4	120.4
23	114.4	117.4	121.5	121.3
24	114.8	117.8	121.6	122.0
27	115.6	119.7	122.6	123.7
30	117.1	122.0	124.0	124.5
36	119.6	124.2	124.1	126.1
42	119.8	124.1	124.6	126.3
48	121.4	124.6	124.7	127.0
60	121.3	124.6	124.7	127.2
Age Month	Weights lbs.	Weights lbs.	Weights lbs.	Weights lbs.
19	504	524	759	732
22	556	587	758	782
28	614	740	726	934
34	687	806	740	981
40	705	800	839	911
46	775	827	850	937
54	763	882	864	924
66	866	895	889	984
78	865	928	...	...

TABLE 19.—INFLUENCE OF AGE AT FIRST CALVING ON GROWTH—HEAVY-FED HOLSTEINS

Age	Early calving four animals	Late calving five animals
Months	Height cm.	Height cm.
19	126.5	127.3
20	126.8	128.9
21	127.8	129.2
22	128.2	130.0
23	128.6	130.3
24	128.9	131.2
27	130.1	133.0
30	131.3	133.9
36	131.9	135.6
42	133.2	136.1
48	133.7	136.0
60	134.1	137.6
Age Months	Weights lbs.	Weights lbs.
19	942	922
21	883	994
27	888	1184
34	963	1225
40	1011	1129
48	1105	1139
54	1118	1121
..	....	....
66	1214	1299
78	1221	1280

first lactation period but until maturity is reached. These data are represented in Fig. 12.

The animals supplying these data are a portion of those which supplied the data in Table 17. All the animals could not be used, since the data did not cover a sufficiently long period of time.

It will be noted in the case of the light-fed Jerseys at nineteen months old that the late calving group was 2.5 centimeters taller at the withers than the early calving group. By the time they were 27 months old the difference was 4.1 centimeters, at 36 months 4.6 centimeters, and when maturity was reached at 60 months the difference was 3.3 centimeters, indicating that the early calving animals were permanently retarded in growth. The same table gives similar data for the heavy-fed Jerseys. At 19 months, the early calving were 1.4 centimeters taller than the late calving group, but at 27 months the conditions were reversed and the late calving group were 1.1 centimeters taller. At 36 months, the difference was still more marked, while at maturity the late calving group was 2.5 centimeters taller. This is a gain of 3.9 centimeters over that made by the early calving group.

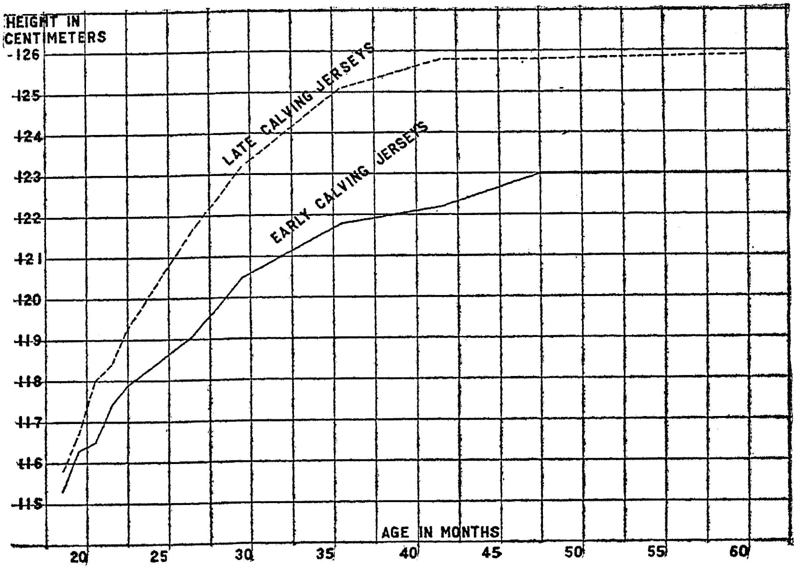

FIG. 12.—The influence of lactation upon skeletal growth. This figure is based upon combined data for groups of heavy- and light-fed Jerseys. The data cover the entire growing period of the animal and show that the early calving group is 2.9 c.m. below the later calving group in height at withers at maturity. (Table 18)

Table 19 shows similar results for the height measurements of the Holsteins. When 19 months old the late calving group was 0.8 centimeter higher than the early calving group. At 27 months this difference had increased to 2.9 centimeters, and at maturity to 3.5 centimeters.

A study of the weights as given in Tables 18 and 19 shows similar results.

The late calving light-fed Jerseys averaged 928 pounds when 78 months old in contrast to 865 pounds for the early calving group. In the heavy-fed Jersey group, altho the late calving animals averaged 27 pounds lighter at 19 months, at maturity they were practically

100 pounds heavier than the early calving group. When 19 months old the early calving group of Holsteins averaged 942 pounds and were 22 pounds heavier than the late calving group. At 78 months the conditions were reversed and the late calving animals averaged 60 pounds heavier than the early calving group. These data show conclusively that lactation is a strong factor affecting growth, since skeleton growth continues at practically a normal rate unless acted upon by some strong factor.

The effect of lactation is not limited to a retardation of growth for a short time, but it is so marked that the final size of the animal at maturity is influenced to some extent by the age at first freshening. This is clearly shown by Tables 18 and 19. These data show that heifers which calve at an early age are generally smaller when mature than those animals which calve for the first time after they are more mature.

The relation of lactation to growth of the heifer is illustrated perhaps to best advantage in Fig. 13.

The weights are given for the early calving group from 9 months previous to the first calving thru two lactation periods and to the point following the third parturition. The late calving group is given at ages corresponding to the early calving group. The data for the individuals are arranged so that the calving points coincide. This figure shows that gestation did not depress the rate of gain. After parturition the early calving group naturally showed a drop in weight which continued for a month, after which there was a fairly constant gain, the rate increasing as the time of second parturition approached.

Following the second parturition the weight again declined and more time elapsed before a gain began. The curve of gain from this point up to third parturition is practically the same as between the first and second parturitions.

The late calving group made far greater gains than did the early calving group during the period which the latter were in milk. After the first parturition by the late calving group the curve of gain is much the same as for the early calving group. It will also be seen that the lead in weight made by the late calving group was still maintained altho not with so wide a variation after the second parturition which coincides with the third for the early calving group.

A study of the data presented leads to the conclusion that lactation is a severe tax upon the growth of a dairy heifer even when the

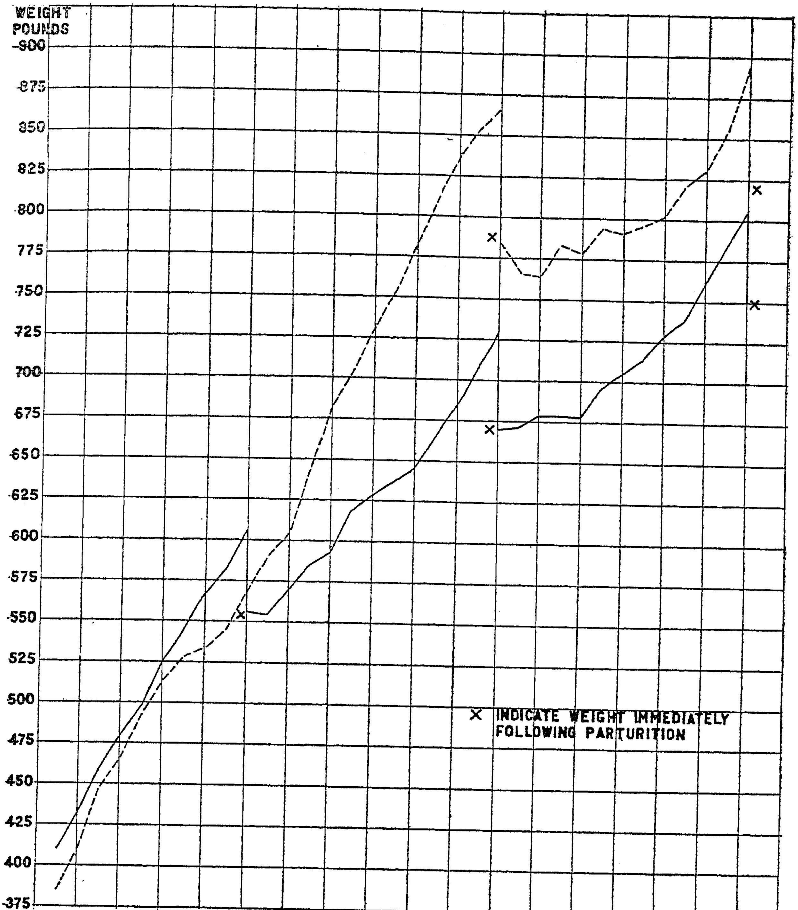

FIG. 13.—The influence of lactation upon growth as represented by weight. The solid line represents a group that calved first at an average age of 22.7 months, the dotted line represents a group that calved for the first time at an average age of 34.9 months, which was practically the same age at which the early calving group dropped their second calves. Note gestation rather increased than decreased the gain in weight but lactation was a decided check. The early calving group weighed 670 pounds after the second parturition and the late calving group 750 after their first. The early calving group regained part of this loss between the second and third parturition but never reached the weights of the late calving group

ration received is ample. Even under favorable conditions of feed and environment the heifer that comes into milk while still considerably short of maturity will not attain as large a size as the animal which is more mature before lactation begins.

The cause of the pronounced effect of lactation upon growth is undoubtedly to be found in the large amount of solids produced in the form of milk by the dairy cow. Even a mediocre heifer which gives no more than 20 pounds of milk daily with a total solid percentage of 12.5 is producing 2.5 pounds of dry matter daily. This is equal to the dry matter in 3.33 pounds of gain on a steer, assuming this gain to contain 75 per cent of dry matter.

If the same calculations are made for a heifer producing fifty pounds or more of milk daily, as is often the case with high bred cattle, it is easy to understand why lactation is a strong tax upon the growing animal.

COMBINED EFFECT OF LACTATION AND RATION

The data presented show clearly that liberality of feeding and age at first calving are both factors which exert considerable influence both upon the rate of growth and the size of the cow at maturity. The most pronounced results would naturally follow a combination of the two. In Table 20 and Fig. 14 are data showing

TABLE 20.—HEAVY RATIONS AND LATE CALVING OR LIGHT RATIONS AND EARLY CALVING

Age	Heavy-fed late calving Jerseys, height	Light-fed early calving Jerseys, height
Months	cm.	cm.
6	94.7	93.1
9	105.0	97.9
12	110.6	103.9
18	117.1	110.3
24	122.0	114.0
30	124.6	116.1
36	126.1	118.9
48	126.9	120.6

the combined effect of these two factors upon two groups of Jersey animals. Beginning at practically the same point at six months there was a constantly increasing difference in measurement up to thirty months. The margin decreased somewhat after this time altho at maturity there was still a difference of 6.3 centimeters in height, or about 20 per cent in total gain in height from the time the animals were six months old. It should be kept in mind also that the light-fed early calving group, which fell so far behind in growth development received an ample ration after first parturition. Had the ration been deficient either in quantity or quality during lactation it is certain that the results would have been even more marked. While hereditary characteristics may in some cases be limiting factors in explaining the numerous undersized cows seen on many farms, it

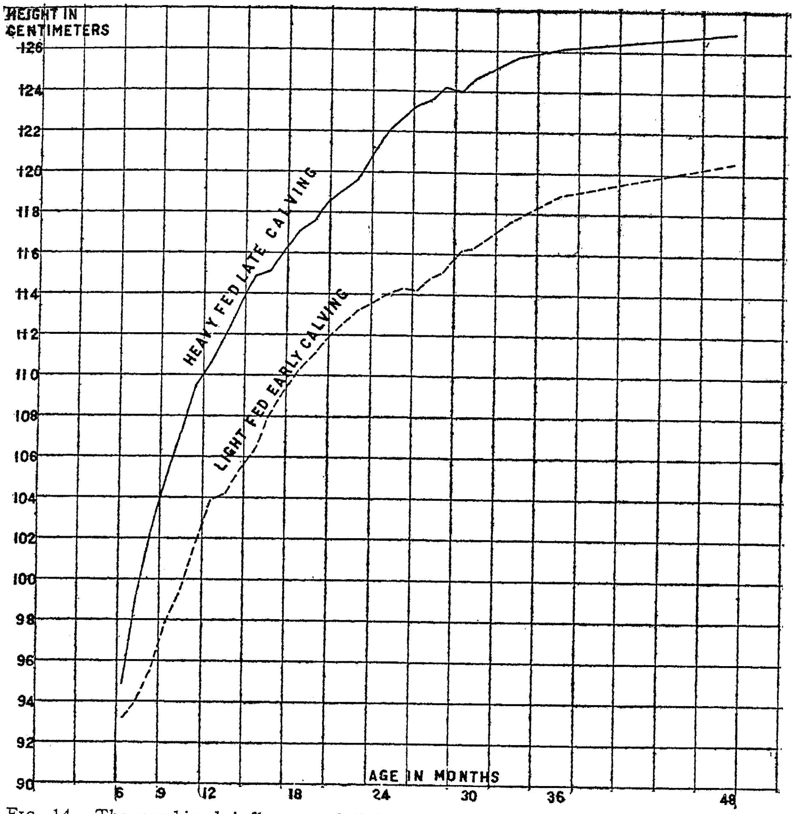

FIG. 14.—The combined influence of light feeding and early calving upon skeletal growth for Jerseys. The light-fed, early calving group was 1.6 c.m. below the other at 6 months while at 48 months, when skeletal growth for Jerseys is practically complete, the difference was 6.3 c.m. The combination of these two factors is a common cause of small cows frequently found in commercial herds. (Table 20)

is believed that the most important factors are a combination of early calving and a scanty ration during the growing period. While heredity is a factor in placing a high upper limit to the size of the large animals observed in some herds it is quite certain that, as a rule, a combination of rather late calving and liberal feeding when young are the more important factors.

HIGH CALCIUM VERSUS LOW CALCIUM RATIONS

The data at hand do not contribute much to the fundamentals of this subject. However, they are of importance in connection with the applications of the laws of growth to domestic animals. The mineral constituents of the ration are looked upon now as more important factors than formerly. The old assumption was that domestic animals secured sufficient mineral matter from any ordinary ration. At present, as a result of the extensive investigations of Forbes, Hart and McCollum, and others, the tendency is to raise the question of possible deficiencies in mineral matter in rations of all farm animals. The data presented were taken in a preliminary trial conducted for the purpose of observing whether or not growing dairy heifers suffered from a deficiency of lime.

Two Jersey heifers were used. They were placed on experiment when approximately six months old and up to this time had received the usual skimmilk ration. The animal which received the low calcium ration was fed corn silage, or at times corn stover, and timothy hay for roughage, and corn and gluten meal for grain. It is unfortunate that the source of the ration was almost entirely the corn plant.

The animal which received the high mineral ration was fed alfalfa hay and a grain mixture composed of corn, wheat bran and a small amount of cottonseed meal. Both rations were carefully regulated to give an ample supply of energy and protein at all times. The calcium and phosphorous in the two rations can be compared from the data in Table 21 based upon analyses of the feeds used.

TABLE 21.—CALCIUM AND PHOSPHOROUS RECEIVED DAILY

Age		No. 85 Low mineral	No. 91 High mineral
Months		grams	grams
7 - 9			
	Ca	5.51	20.44
	Ph	7.84	18.16
10 - 12			
	Ca	9.25	28.49
	Ph	10.11	25.05
13 - 15			
	Ca	6.76	28.29
	Ph	9.84	25.01
16 - 18			
	Ca	5.95	27.81
	Ph	8.78	21.88

The animal on the low mineral ration, as far as could be determined by appearances, thrived and apparently was in a normal condition until she was nearly 18 months old and had been fed the ration for 13 months. She then began to show symptoms of an abnormal condition. The first indication was a stiffness in the joints and an abnormal gait in walking which gradually became worse until the animal walked with the knees partially bent and she could not get up from a lying postion except with great difficulty. By making a decided change in ration and by giving bone meal liberally it was possible to restore the condition of this heifer to nearly normal within a month. The heifer which received the high mineral ration made excellent growth and remained in splendid physical condition at all times. The data in Table 22 give the normal height and weight

TABLE 22.—RELATION OF CALCIUM SUPPLY TO GROWTH

Age	Weight			Height		
	Normal weight	No. 85 low calcium ration	No. 91 high calcium ration	Normal height	No. 85 low calcium ration	No. 91 high calcium ration
Months	lbs.	lbs.	lbs.	cm.	cm.	cm.
6	260	...	205	93.7	....	92.0
7	302	263	234	96.8	....	94.0
8	340	271	272	99.8	98.0	97.5
9	376	323	308	102.8	99.5	99.5
10	407	374	344	105.0	102.5	102.8
11	432	419	379	106.5	105.0	105.0
12	456	456	406	108.3	106.0	106.5
13	480	485	421	110.1	110.3	108.0
14	503	526	450	111.4	109.3	108.8
15	528	547	483	112.7	111.3	109.0
16	533	562	501	113.4	110.5	111.0
17	553	582	532	114.6	112.5	113.3
18	572	589	555	115.6	115.0	115.0
19	598	...	572	116.8	116.5	115.8
20	621	...	591	117.5	117.5	117.5
21	649	...	615	117.9	118.0	117.5
22	668	...	634	119.1	119.5	118.5

for an animal of the Jersey breed and also the weight and height for the two experimental animals up to 22 months. The weight figures for the animal on the low mineral ration are given up to 18 months only, the point where the break down in condition occurred. The same data are given graphically in Fig. 15. The result was that the animal which received the ration low in calcium made a perfectly normal growth both in height and weight and made a growth equal to the animal receiving the high mineral ration.

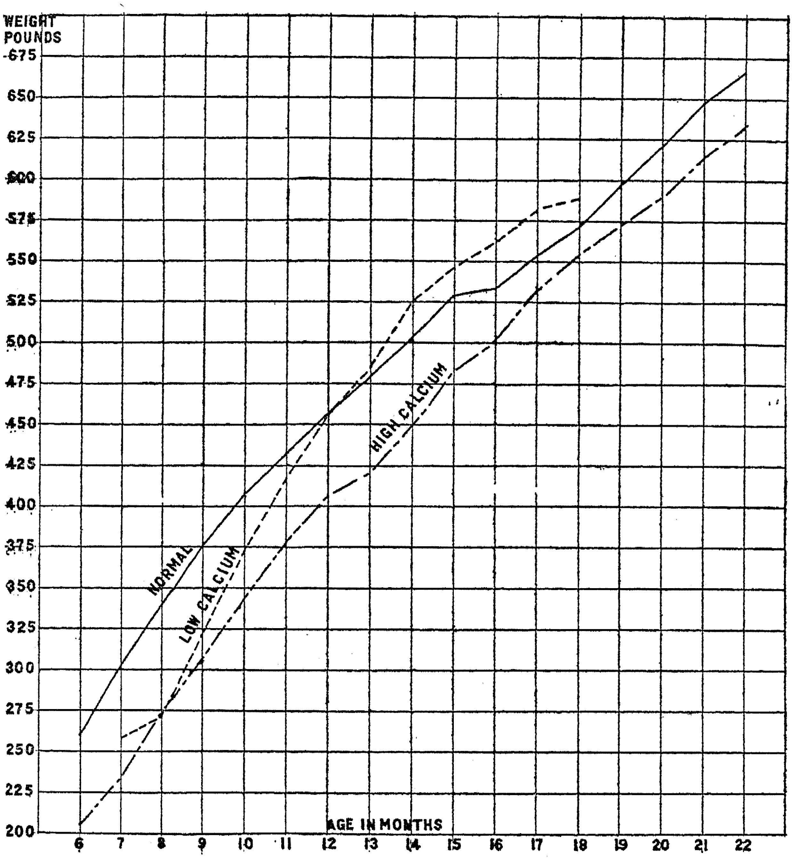

FIG. 15.—The calcium supply in relation to growth. The normal weight for Jerseys at this age is shown by the solid line. The line marked "low calcium" represents the weight of a Jersey receiving from 5 to 9 grams of calcium daily. This amount was so deficient that a general physical breakdown occurred at 18 months. The "high calcium" line represents the weight of a Jersey receiving from 20 to 29 grams of calcium daily. This animal remained in perfect health until taken off this experiment, which was more than a year after the breakdown of the other animal. The result with skeletal growth was almost identical with that of weight, indicating that the first effect of a "low calcium" supply in the ration manifests itself in a general physical breakdown and not by a retardation in the rate of growth. (Table 22)

An examination of the literature concerning the relation of the amount of calcium in the ration to growth reveals that similar observations have been made on other animals. Voit[15] concluded from his experiments that animals which received rations low in mineral matter, but otherwise normal and abundant, increase normally in weight; and the first result of low calcium feeding is an abnormal condition of the bones generally described as rickets. Aron and Sebauer[16] compared the rate of gains made by dogs fed on a ration high in calcium with gains made by similar animals on a ration deficient in this mineral. The rate of gain was practically the same for both rations altho the deficiency in calcium was so great in the one that the bones of the animal which received it were badly affected. The symptoms were those of rickets. While the gains in weight by the animals on the low calcium ration were not affected, it was noticeable that the movements of the animals were hindered and that there was a tendency for a nervous breakdown and digestive disturbances.

While the data presented are too limited to justify any definite conclusions, it is doubtful under practical feeding conditions if the calcium supply will either limit or accelerate the rate of growth of dairy cattle, or prove to be a factor of importance in determining their size when mature.

RECOVERY FROM RETARDED GROWTH

The results obtained by the authors with dairy cattle bear out to a great extent the conclusions of Waters[17] to the effect that there is clearly a strong tendency to compensate for adverse conditions which have retarded the growth of the animal and kept it below the normal. There are two ways in which recovery may take place; (1) by an increase in the rate of growth after the period of adversity is past; (2) by prolongation of the period of growth. When an animal, which has been retarded in growth because of an inferior ration, is given an ample ration, the tendency is strong to use a very large amount of food and to make a growth in excess of the normal rate, and in this manner again to approach the normal size for the breed and age represented. On the other hand, an animal which has made growth above the normal because of a very liberal ration shows a marked retardation when the conditions become less favorable. Conditions which may cause a growth above normal for a group of animals under low conditions of nutrition may cause a growth below normal for a group that is above normal as the result of a period of high nutrition. These results are shown clearly by data taken in connection with experiments on wintering dairy heifers.

One group of these heifers received a ration sufficient to bring about a daily gain of 1.65 pounds during a six months wintering period. A second group was fed a ration which resulted in an average daily gain of 0.36 pounds. At the end of the six months wintering period both groups were placed on pasture. The results are given in Table 23 in the form of gain in weight and height at

TABLE 23.—COMPARISON OF WINTER AND SUMMER GAINS IN PER CENT OF THE NORMAL

	Group 1 Gain 1.65 lbs. daily in winter	Group 2 Gain .36 lbs. daily in winter
Winter 6 months		
Gain in weight	191	15
Gain in height	145	97
Summer, 6 months on pasture		
Gain in weight......	43	102
Gain in height	85	119

withers in per cent of the normals. These data show a marked difference in gain by the two groups as compared with the normal. The group which received the liberal ration in winter gained less than the normal the following summer, while under the same pasturing conditions the group that made a gain far below the normal during the winter made a gain above normal both in weight and height.

The second method of recovery from a stunted condition is bv a prolongation of the period of growth. The heavy-fed animal reaches a comparatively early maturity. The light-fed animal grows more slowly and for a longer period of time until a more avanced age has been reached. In some cases the light-fed animal may completely recover when placed on a more liberal ration. In a few cases such an animal has been known to reach a size even greater than that of an animal which has been given a good ration and has made a steady and liberal growth from birth. An example of such a case is shown for two individuals in Fig. 16. As would be expected, the figures for a large group are not so extreme or striking.

Table 24 shows the relative size of the heavy versus light-fed Holsteins and Jerseys and the difference in centimeters at each point. This shows that with both breeds there is a strong tendency for the heavy-fed animals to cease growing some time before cessation comes to the light-fed group. It is doubtful if on the average, the

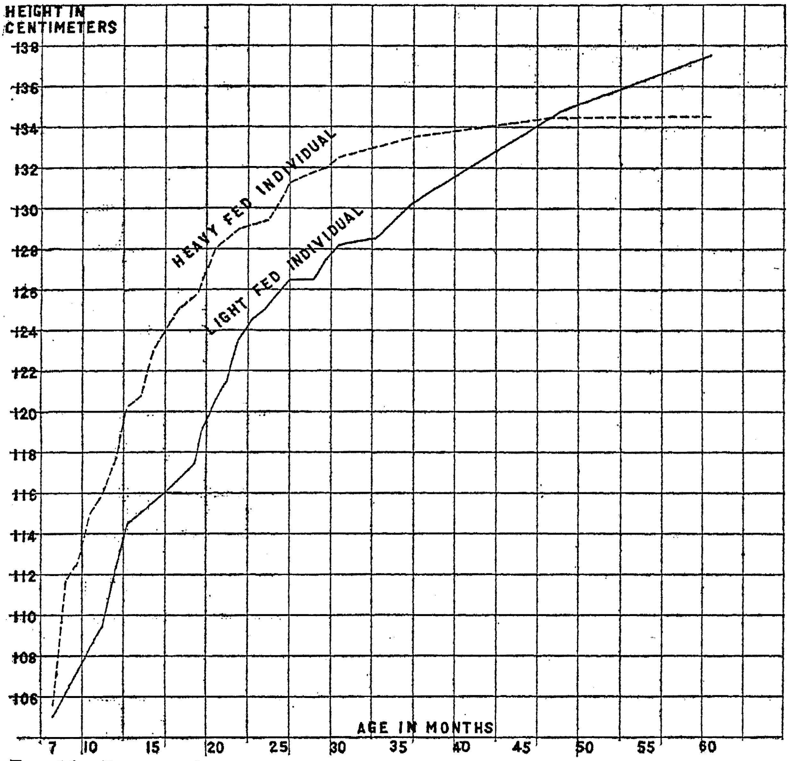

FIG. 16.—Recovery from poor nutrition thru prolongation of growth. Each line represent an animal. The two were practically the same height at 6 months of age. The heavy-fed animal made a more rapid growth and reached maturity quicker. With the light-fed animal the period of growth was greatly prolonged and she was taller at maturity than the heavy-fed animal. The growth of these two cows is typical of the results obtained with groups except that on the average the light-fed animals did not reach the size of the heavy-fed ones

light-fed animal will ever attain the size of the heavy-fed animal altho it has a strong tendency in that direction.

The same was observed by Waters[18] who states that it is possible to recuperate by prolonging to some extent the period of growth but, "just to what extent this is possible we cannot yet form even an estimate, but results already obtained indicate quite clearly that an animal when sparsely fed thru the early part of its life may grow after the time when an animal that was normally nourished is matured and has ceased to grow."

TABLE 24.—RELATIVE SIZE OF HEAVY VS. LIGHT-FED HOLSTEINS AND JERSEYS AND DIFFERENCE IN CENTIMETERS AT EACH POINT

Age in months	Holsteins			Jerseys		
	Heavy-fed	Light-fed	Difference in centi-meters	Heavy-fed	Light-fed	Difference in centi-meters
1	76.7	75.6	1.1	70.1	71.6	—1.5
2	81.7	80.4	1.3	73.1	75.9	—2.8
3	88.1	84.6	3.5	77.9	80.5	—2.6
6	103.4	96.7	6.7	92.7	92.3	+ .4
9	111.5	101.2	10.3	102.2	97.2	5.0
12	117.8	106.3	11.5	108.8	102.5	6.3
18	125.4	115.3	10.1	116.6	110.6	6.0
24	130.1	121.6	8.5	121.8	116.3	5.5
36	133.7	126.9	6.8	125.1	121.9	3.2
48	134.9	129.5	5.4	125.7	123.0	2.7

CONCLUSIONS

Measuring growth.—It is concluded from the data presented that it is impossible to represent the growth of an animal by a single term. It appears necessary to use one unit to measure the growth of the skeleton and another for the gain in weight. The growth impulse is decidedly stronger in the skeleton than in the fleshy parts of the body. Environmental conditions of the growing animal have a much stronger effect upon the weight than upon the growth of skeleton. A difference in rations fed that resulted in a variation of 46 per cent in gain in weight between two groups resulted in a difference of only 7 per cent in the growth of the skeleton.

A study of monthly measurements taken on 16 dairy heifers from birth to maturity leads to the conclusion that any one of several skeletal measurements may be used as a measure of the growth of the skeleton. On account of the small limit of error, and the ease with which it is taken, the height at withers is selected as the measure of skeletal growth. The growth of the animals is measured by two units, (1) gain in live weight, (2) increase in height at withers.

Size of calf at birth.—Little, if any, relation can be found between the size of the calf at birth and the rate of growth or the size of the animal at maturity.

Breed as a factor in growth.—The rate of growth in skeleton by the Jersey and Holstein is practically the same from birth to 24 months but is greater by the Holsteins from this date on. The rate of gain in weight from birth is somewhat greater by the Holsteins. There is a well marked breed characteristic with reference to the age at maturity. The Jersey reaches maturity in skeletal growth between 3 and 4 years, the Holstein between 4 and 5 years. The maximum weight is reached by both breeds about two years after the growth of skeleton ceases.

Liberality of the ration.—The amount of digestible nutrients consumed during the growing period has some effect upon the rate of growth of the skeleton, but the relation to the weight is much more pronounced. A ration supplying a large amount of readily digestible nutrients increases the rate of growth, especially in weight; hastens the time of maturity; and allows the animal to develop to the full limit of its inheritance. The animal which receives less nutrients in its ration during the growing period is thinner in flesh; and if the plane of nutrition is decidedly lower, the rate of skeletal growth is also slower, the growth period is somewhat prolonged; and the tendency is for the animal at maturity to be smaller than the one raised on a liberal ration.

Gestation.—Gestation has practically no effect upon the rate of growth of heifers. This is in keeping with previous investigations of this Experiment Station which indicate that developing the fetus exerts but a slight tax upon the animal.

Lactation.—The growth of a lactating animal is checked materially both in regard to the skeleton and the weight. Heifers in milk make decidedly less growth than animals of the same age and breed that are farrow or pregnant. The effect of early lactation is sufficient to check the growth of the animal to the extent that the size at maturity is somewhat influenced. Heifers which calve when 20 to 24 months old do not average so large at maturity as heifers that calve first when 28 to 34 months old.

Combination of early calving and light rations.—The most decided effect upon the size of dairy cows when mature results from a combination of light rations during the growing period and early calving. It is believed that next to hereditary factors which may determine the upward limit of growth, the combination of early calving and light rations during the growing period is the main cause for the numerous undersized cows in many commercial herds.

Relation of calcium in the ration to growth.—A Jersey heifer 6 months old was placed on a ration so low in calcium that a physical breakdown occurred at the end of 13 months. Her rate of growth was compared with that of a heifer which received a high calcium ration. The rate of growth by the two was practically the same and was equal to the normal up to the time of the breakdown of the one which received the low calcium ration. This result is in accordance with investigations conducted with other animals which indicate that the rate of growth is not appreciably affected by the amount of calcium supplied, and that the first indications of a deficiency of this constituent is a physical breakdown.

Recovery from retarded growth.—There is a strong tendency for animals to recover from retarded growth if conditions are favorable later. This may be accomplished by a more rapid rate of growth or by prolonging the period of growth. If the retardation, especially in skeletal growth, has gone too far the animals will not, however, reach the normal size.

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