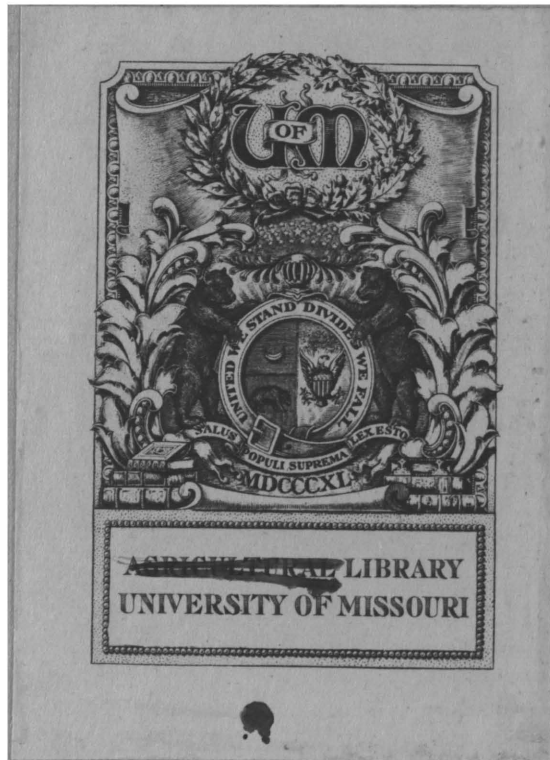


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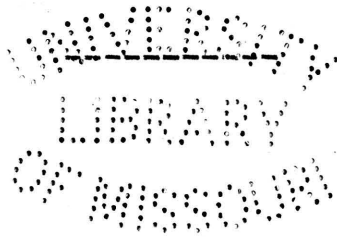
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C. H. Eckler

THE EFFECT OF LACTATION ON GROWTH

by

William Michael Regan, B. S.



SUBMITTED IN PARTIAL FULFILLMENT
OF THE REQUIREMENTS FOR THE
DEGREE OF MASTER OF
ARTS
in the
GRADUATE SCHOOL
of the
UNIVERSITY OF MISSOURI

1914

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DISCUSSION OF GROWTH.

While as yet no exact definition of growth has been formulated by scientists, it is usually considered as that series of changes through which an organism passes from beginning to the end of its life. By the fusion of the sperm and the egg an impulse to grow is imparted. This impulse, under favorable conditions of environment, will cause the resultant of these two sexual cells to pass through the definite series of changes which are characteristic of that particular species of organism. As this impulse is gradually used up, we say that the animal grows old; death, barring accidents, is a cessation of the impulse to grow.

The above attempt to define growth is necessarily very vague when we consider that this impulse to grow is probably identical with the vital force and to answer the question "what is growth?" would be to answer the question what is life, a question that has puzzled the minds of men since the beginning of time.

Many theories have been formulated at different times to explain this growth force, but none of these have been at best more than mere guesses, because they have not been backed by any accumulation of facts. Very little work has been done towards the study of the way in which growth acts and as suggested by Minot the best method of

doing this is by studying those changes in the organism which are attendant upon growth.

Of these many complex changes which accompany the using of the impulse to grow most of them are invisible to the eye and are of such a nature that it is either impossible or very difficult to measure them. However, certain of the changes are very apparent and do lend themselves readily to measurement.

A study of growth should then properly begin with a study of these changes and the factors by which these changes may be affected. With this in view and also with a view of determining, if possible, the effect of immature calving on the dairy cow, I have chosen the subject of my thesis "The Effect of Lactation on Growth," which as will be shown later also involves the study of the effect of growth on lactation.

Of the visible and measureable changes which attend the growth process of the individual those changes in size and shape are by far the most apparent. And because of the fact that a greater part of the change in the shape of the organism especially with mammals comes during the prenatal period, we have come to consider

growth as a change in size and since the growth process is progressive, as an increase in size. Thus far all of the work that has been done along this line has assumed the nature of the study of growth changes as indicated by a change in size of the individual

Literature

Probably the first and most extensive study of the general nature of growth was made by C. S. Minot* of Harvard Medical School. He used as his subject guinea pigs, kept as nearly as possible under normal conditions, using the changes in body weights as an indication of growth. More than 400 pigs were used in the experiment, and a total of 8040 weights were taken.

Minot chose as method of studying the changes in body weight, the rate at which the weight changed. With regard to this he says, "Growing old is a very complex process, of which no concise definition can be given by the morphologist or physiologist as yet. Of all the occurring changes none are more characteristic of age than the loss of power of growth, and to ascertain how that loss occurs is an important preliminary to the further study of the effects of age. The loss of the power to grow is properly speaking a change in the

*Journal of Physiology, Vol XII, 1891. Senescence and Rejuvenation.

rate of growth."

Most of his work was taken up with a study of the changes in rate of growth which occur normally in guinea pigs, from birth to old age. He presents some 30 tables and charts from which he draws the following conclusions. "I think it is now conclusively shown that there is in guinea pigs a progressive loss in the power of growth beginning almost immediately after birth. The loss of growth power as will be shown in subsequent articles* is equally demonstrable in the case of man, of other animals, and there can be little doubt that it is true at least of all mammals. This conclusion raises the question whether other animals do not obey the same law, and suggests to the more general problem whether in all living beings there is not a certain impulse given at the time of impregnation and whether the impulse does not gradually fade out so that from the very beginning of the new growth there occurs a diminution in the rate of growth. The problem seems to me to possess a very profound interest because its solution, if I foresee correctly, would enable us to determine with precision a general characteristic of life."

*These "subsequent articles" to which he refers I have not been able to find.

No. not prob. refer.

Along the same line Howell says, "The body increases rapidly after birth in size and weight. It is the popular idea that the rate of growth increases up to maturity and then declines as old age advances. As a matter of fact, a careful examination of the facts shows that the rate of growth decreases from birth to old age, though not uniformly. At the pubertal period and at other times its downward tendency may be checked for a time. But speaking generally the maximum rate of growth is reached sometime during the intrauterine period, and after birth the curve steadily falls.

A further study of growth as evidenced by a change in size and shape was made by H. J. Waters* in 1908. In this work steers were used and body measurements were taken as the measure of growth. The growth of steers on full feed, maintenance and sub-maintenance were compared. The data is presented in tables and curves. The following are the ^{Hy. U.?} conclusions.

"Our studies of the growth of animals and the factors affecting the same have already progressed far enough to indicate clearly that sole reliance need not and, in farm practice usually is not, placed upon any single way of reaching this end. What might be termed

*Capacity of animals to grow under adverse conditions. Society for the promotion of Agr. Science, 1908.

the law of physiological compensation seems to apply with particular force in the matter of growth.

Apparently the animal has recourse to any or all the following ways to reach a normal size:

First, by growing steadily from birth to maturity, as with a uniform and ample food supply.

Second, as pointed out in this article, by storing fat in a period of abundant food supply to assist in tiding over a limited period of sparse food supply without serious interruption of growth.

Third, by prolonging somewhat the growth period. 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 through 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.

Fourth, by an increase in the rate of growth in a period of liberal feeding following a period of low nourishment apparently has the capacity, when liberally fed, to compensate for this loss in a measure at least, by an increased rate of gain.

Fifth, by conserving the cost. Apparently the animal organism, when kept for a long period of time on a low nutritive plane, as in the case of maintenance animals, gets on a more economical basis than when more liberally fed. For example, if we reduce the feed of an animal that has been previously liberally nourished, to a point where for a month or more there is a small loss in weight, and equilibrium will later be established and subsequently the animal may increase in weight, the quantity and quality of the food remaining the same. Thus a ration that was insufficient to sustain live weight at first may be capable later of maintaining the animal at a stationary body weight, and still later of causing an increase in weight. Digestion experiments with a number of animals indicate that a part of this is due to the more complete digestion of the food by the animal in a low nutritive plane, but so far as the experiments have thus far progressed there does not seem to have been a sufficient increase in the degree to which

the food has been digested to account for all the increased efficiency in the ration noted."

The study of hormones and their effect upon the various functions of the organism have led to some very interesting discoveries certain of which are along the line of growth. It has been shown that the removal of certain of these glands which produce specific hormones has a decidedly depressing effect on the general growth of the animal. By feeding extracts of the gland the animal quickly recovers and again resumes normal growth. Because of our present meager knowledge of hormones and their action it is impossible to say in what manner they affect growth. Some have gone so far as to assume that these hormones themselves furnish the growth force while others hold that they only affect the growth force in so far as they check it by bringing about a condition of malnutrition. Never-the-less whatever their action may be they must be considered as having profound influence in bringing about normal growth.

Discussion of Lactation.

By lactation is meant the process of milk secretion. At the time of conception certain profound changes are initiated in the maternal organism. And there can be little doubt that in some way these changes are intimately connected with the process of milk secretion which normally begins at the time of parturition. At the time of parturition the stimulation to produce milk becomes active. A certain definite amount of stimulation is acquired by the mother which under favorable conditions of food and care will cause her to produce a definite amount of milk. Of the cause and nature of this stimulation as yet but little is known.

The anatomical structures which take part in the process of milk secretion have been very extensively studied and are pretty well understood. It has also been pretty well established that the process is essentially one of the manufacture in which the cells of the udder play the part of a manufacturing plant elaborating the normal constituents of the blood and lymph into those constituents which are

normally found in milk. But as yet the physiological changes by which the process of milk secretion is attended are as little understood as those which accompany growth. And until they are better known no intelligent understanding of the process can be had.

Lactation and Growth Compared

A comparison of the general character of growth and lactation shows a striking similarity. Both are dependent upon sexual reproduction for initial stimulus. Under favorable conditions the size and shape to which an animal will attain and the amount and quality of milk a cow will give are determined by heredity. The rate of growth from birth to old age and the rate of milk production from the beginning to the end of the lactation period follow curves that are strikingly similar in form, being highest near the beginning and gradually falling to the end. This shows that the impulse to grow and the stimulation to give milk are used up in much the same manner.

Both growth and milk production show identical reaction to the same factors. Unfavorable conditions

of nutrition and environment serve to check the growth and milk production. The amount of the check in both cases depending to a large extent upon how unfavorable the conditions are. By again resuming favorable conditions in both cases there is a tendency for the animal to again approach at least, the previous rate of growth and milk production.

It has been shown that with the process of milk secretion as with the growth process certain of the ductless glands play an important part. Extracts of the pituitary body injected into lactating cats and goats caused an immediate and increased secretion of milk. Here again the two processes show a striking similarity. Because of these very apparent likenesses between the two processes under consideration it seems to me that a study of either process may lead to a better understanding of the other.

The impulse to grow and the stimulation to produce milk (in the case of the high class dairy cow) have been shown to be strong forces in the life of

-16-

the animal. Waters in his work shows that a steer will grow steadily in height when kept on maintenance and even when starving. A cow which was known to have the stimulation to produce milk developed to a high degree was kept on a sub-maintenance ration for 22 days after calving. At the end of this time she had only fallen off a couple of pounds in her daily milk yield. ^{But} She was in such an emaciated condition and her vitality was so low that she could not arise without assistance. She was then put gradually on full feed and again soon recovered. From this it would appear that the demands of both milk production and growth on the available supply of nutrients are satisfied before that of maintenance.

The Problem

There are five uses in general to which a dairy cow may put her feed. It may be used for maintenance, for growth, for the production of milk, for the laying on of fat and for the growth of the foetus. This latter as shown by the work of Mr. K. B. Musser* being of very little importance when considered from

*Thesis, "Cost of Production of Foetus," presented for M. A., U. of Mo., 1914.

from the standpoint of the amount of nutrients actually required to develop the foetus. In view of the fact that steers continued to grow when on sub-maintenance and the highly developed dairy cow continued to give milk when starving, it seems to me that it would be interesting and important to determine if possible what happens when the impulse to grow and the stimulation to give milk are operative at the same time and at a time when from the standpoint of nutrition the animal has only about enough feed to satisfy one of the requirements. Does the animal stop growing and continue with the milk flow unaffected, or are the requirements for growth first satisfied and the remaining nutrients used for milk production, or is there a middle ground and each process suffers to a limited extent?

Then too there arise practical questions. Can a dairyman afford to have his cows come into milk before they are full grown? By so doing will the animals be permanently stunted or will the amount of milk that the animal will be able to give be very materially lessened? Just how early will it be

practical to have heifers calve?

Discussion of Data

In the spring of 1906 "a study of certain factors regarding the development of dairy cattle" was begun at the Missouri Station. Since that time a vast amount of data have been accumulated and it is by a study of a portion of these data that I am going to attempt to indicate at least answers to the above questions.

Animals Used: The cows used were purebreds of the Holstein, Jersey, and Ayrshire breeds. The calves were put in their respective groups as soon after as they appeared to be normal as regards health and strength. The individuals of each group were balanced against each other with respect to breeding as nearly as it was found possible to do so.

Grouping: The animals from which the data were taken were divided into two general groups. The first group included 14 animals which were fed a heavy ration from birth to first calving. The second included 15 animals fed a light ration from birth to first calving. For convenience in the discussion, these groups will hereafter be designated

as the "heavy fed group" and the "light fed group." Each of these groups was subdivided, half of them being bred to calve early, 20 to 22 months, the other half were bred to calve late, 34 to 36 months.

Treatment of Animals: The animals in each group received identical treatment with the exception that they got different rations until the time of first calving. The calves were taken from their mothers when they were five or six days old. The light fed calves received whole milk until they were two weeks old, then they were gradually changed to skim milk. The heavy fed calves were kept on whole milk until they were weaned, both groups being weaned at the age of six months. Care was taken with the feeding so that the animals were kept in the best possible condition.

A mixture of 2 parts of corn and 1 part of oats was fed the heavy fed group. After they were about four weeks old they were given all of this grain mixture that they would clean up. The light fed group received no grain until after they calved. Both groups were given all the good alfalfa hay they would eat. They had access to salt at all times.

After calving both groups were given a ration made up of 4 parts of corn, 2 parts of bran, and 1 part of linseed meal. This was fed according to the milk yield, giving one pound of grain to each three pounds of milk. They were given about all the corn silage and good alfalfa hay that they would eat. A complete feed record was kept of each animal as long as it was thought to be growing.

Taking of Data: Weights and measurements were taken on each animal from the time of birth until it was decided that it had stopped growing. Weights were taken on each animal at about 8:30 A. M. on three mornings usually the 13th, 14th, and 15th of the month and an average of these three weights was taken as the weight for the month. The animals were kept away from water and feed from the evening before weighing until after they were weighed. This was done in an attempt to make the weighings as uniform as possible.

Besides the weights monthly measurements were taken on each animal throughout its growing period. The same precautions for having the animals in uniform conditions were observed as with the weights.

The animals were measured but once during the month. The following were the measurements taken:-

1. Height at withers.
2. Height at highest points of croup.
3. Height of hip points.
4. Depth of chest just behind elbow joint.
5. Width of chest just behind elbow joint.
6. Width of hips.
7. Width of loin.
8. Length from pole 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 the hips.
13. From a line between hips to the 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.
18. Heart girth behind elbow joint.
19. Girth of paunch at end of last rib.

Discussion of Measurements: Necessarily in a study of growth the first important step is that of choosing a reliable means of measuring the growth. In general an animal grows, i.e., increases in size, in two ways. It may get larger by increasing in skeletal measurement and as shown by the work of Waters, this may take place at a time when the animal is losing in weight. The animal may increase in size by increasing in weight, and it is evident that an animal may increase very rapidly in weight at a time when skeletal measurements show very little or no increase. This condition would obtain when a mature cow lays on fat. Then too the boney skeleton of the animal and the muscular frame work depend on quite different types of nutrition for their growth, and it is possible for an animal to be so nourished that one would be developed while the other would grow but little. So it seemed probable that a consideration of both weights and measurements would better define the growth of the animal than a consideration of either of these alone.

Of the 19 measurements taken it became necessary to choose some few that could be used reliably to measure the growth. A good many of the measurements

taken were found to be useless because they were so greatly affected by the relative physical condition of the animal from one month to the next. Examples of this kind of measurements are the heart girth and ponch girth. Other measurements were so small and the growth of the parts so slow that the difference from one month's measurement to the next fell well within the limits of experimental error. An example of this is the measurement of the circumference of the shin bone. The height at withers, the width of hips, and the height at hip points appeared to be the most reliable measurements to use.

Upon studying these three measurements it was found by Professor Eckles that when plotted on the basis of per cent gain that each of these measurements showed practically the same curves. From which we would infer that one of these measurements gave about as good an idea of the animal's growth as all three of them would. So I chose the measurement of the height at withers because it seemed to me to be the most "clean cut" measurement and less liable to fluctuations, due to the condition of the animal. The measurement was large enough so that a small error in measurement would not render the results valueless

and because the measurements were made at a fixed and sharply defined point they should be uniform from month to month.

A Source of Error in Taking Measurements at Withers: Upon examining the data taken for this measurement fluctuations from one measuring to the next were found which were too large to be considered as errors in measurement. An animal would be shown as being two or three centimeters lower than it had been the month previous. By examining the method of measurement the reason for this apparent loss of growth was found. A close examination of an animal that was being measured showed that the animal after being allowed to come to rest immediately began to decrease in height. The back bone was observed to sink from an inch or so above the shoulder blades until the top of the shoulder blades instead of the backbone was the highest point of the withers.

This is probably due to relaxation and stretching of certain large muscles which attach on the sternum and shoulder blades and serve to hold the body up. Probably the muscles that are mostly concerned are the

anterior and posterior pectorals, the serratus thoracis, and the serratus cervicis.

When the animal is in motion these muscles are tense and hold the body well up between the shoulder blades but as soon as the animal comes to rest these muscles relax and this together with a certain amount of stretching allows the thorax to be lowered slightly while the shoulder blades remain stationary. Upon resuming motion they again contract and the animal assumes its maximum height. A measurement taken from the top of the scapula should be more accurate. In view of these facts I have taken the liberty to correct certain errors in the data that were plainly the result of this cause.

Weights Discussed: The only available measure of the actual increase of body substance is that of weight. This increase in body weight cannot always be attributed to growth. And an increase in weight can be interpreted as indicating growth only within certain limits. However, I think that with a proper understanding of the limitations that are attendant upon the use of body weight as an indication of growth that it may be safely used in connection with skeletal

measurements to determine the size of the animal. An examination of the monthly weights show frequent fluctuations for which as yet no adequate explanation has been given. The following data is given as an example of these fluctuations.

Weight in Pounds								
No. Cow:	January 1912				February 1912			
	14	15	16	Av.	Av.	14	15	16
218	1005	1031	1005	1014	1041	1035	1053	1034
223	1041	1080	1055	1059	1098	1081	1103	1110
222	855	872	859	862	866	854	883	860
11	722	718	692	711	703	700	708	700
13	785	795	773	784	779	773	785	778
306	966	999	960	975	832	827	830	832
307	771	805	795	790	834	820	847	834
14	697	710	670	692	699	691	713	695
224	755	772	768	765	784	772	806	774
227	846	852	842	847	835	819	855	830
228	768	787	772	776	748	752	749	743
22	610	640	607	619	639	633	642	644
23	915	937	892	948	907	898	925	898
225	872	900	875	882	906	897	911	910
17	730	690	730	717	734	723	750	728
Total	12338	12588	12295	12441	12405	12275	122560	12376

An examination of the above data shows that there is a considerable variation from one daily weight to the next. This variation seems to be general. That is there are very few cows that do not show a variation. This variation ranges from a few pounds up to 60 pounds, in most cases being above 20 pounds. All of the animals seem to show a variation in the same direction. That is if one animal markedly low on the 14th all of the animals show the same thing to a more or less extent. From which one might be led to believe that that same factor is operating on every member of the group to cause the variation. A possible explanation of this might be found in the difference in temperature or relative humidity of the atmosphere between the two days. This factor would to a certain extent control the evaporation from the surface of the animal and consequently affect the weight.

It is also noticed that there is an apparent oscillation of the weights. If all the weights are very low on one day they are liable to be high on the next and low on the following.

The variations between the average of the 3 days for one month and the average of the 3 days for the following month, in general, are less than the

variations between the daily weights of one month. The monthly averages tend to show to a less marked degree the oscillation exhibited by the daily weights.

The following table shows the total weights and averages of the 15 cows in the previous table for each of the three days by month.

Months 1912	1st Day	2nd Day	3rd Day	Average
Nov.	12019	12265	12250	12179
Dec.	12492	12614	12533	12547
1913				
Jan.	12338	12588	12295	12441
Feb.	12275	12560	12376	12405
Mar.	12553	12522	12784	12620
April	12338	12505	12437	12426
May	12628	12772	12645	12648
June	12963	12932	12810	12907
July	12607	12605	12792	12733
Aug.	12933	12740	12751	12758
Sept.	12593	12497	12551	12548
Oct.	13024	12040	12985	13021
Nov.	13091	13012	12196	13100
Dec.	13318	13177	12582	13354
1914				
Jan.	13606	13567	12604	13579

This table shows the oscillations in weights to a marked degree. There is but one exception to this general conclusion. When the weight on the first day is lower than the weight on the second day, the weight on the third day is also lower than that of the second day, but if the weight on the first day is higher than that on the second day then also the weight on the third day will be higher than that on the second, showing that when a factor operates to change the weight in one direction there is also an influence which operates to change the weight in the opposite direction on the following day.

Another circumstance enters in which renders weights an unsatisfactory method of measuring growth with animals in milk; and that is the marked loss in weight which a cow shows when she comes in lactation. This loss as will be shown in subsequent tables begins as soon as the cow freshens, and continues in some cases for 3 or 4 months.

Because of these facts I have chosen to use both the body weights and height of withers measurement in my measurement of growth.

Does Lactation Affect Growth?

It was pointed out in the preliminary discussion that the impulse to grow and the stimulation to give

milk were not only two of the strongest forces in the make up of a dairy cow but that in a good many respects they seem to be antagonistic to each other. So as a necessary preliminary to the discussion of the effect of lactation on growth I think it is necessary to answer the two questions, does growth affect lactation and does lactation affect growth?

As a means of studying this question I have used a comparison of the Early and Late Calving division of the light fed group. Animals that were abnormal in any way were discarded.

Ten animals, six Jerseys, two Holsteins, and two Ayrshires were used in the early calving group. The late calving group comprised of six animals, 3 Jerseys and 3 Holsteins.

The average height at withers for the animals of each of these groups are shown in Table II. This is shown graphically in Plate I. A reference to Table II shows that at 18 months of age the late calving group were 115.2 c. m. high and the average of the height of the early calving group was 114.1 c. m. This was 6 months before cows of the early calving group freshened. From this time on the early calving

TABLE II.

EFFECT OF LACTATION ON GROWTH

Light Fed Late Calving Compared To
Light Fed Early Calving.

Age in Months:	Height at Withers in C. M.		Difference
	Late Calving	Early Calving	
18	115.2	114.1	1.1
19	116.0	114.7	1.3
20	117.5	115.4	2.1
21	118.6	116.2	2.4
22	119.3	117.2	2.1
23	120.1	117.7*	2.4
Gain in C. M.	4.9	3.6	
Gain in Per Cent	4.2%	3.1%	
24	121.0	118.1	2.9
25	121.9	118.3	3.6
26	122.4	118.5	3.9
27	123.5	119.0	4.5
28	124.2	119.5	4.7
29	125.1	121.0	5.0
30	125.5	120.6	4.9
31	126.2	121.1	5.1
32	126.6	121.9	4.7
33	127.0	122.6	4.4
34	127.3	123.0	4.3
35	127.5*	123.7*	3.8
Gain in C. M.	7.4	6.0	
Gain in Per Cent	6.1%	4.8%	
36	127.7	123.6	4.1
37	127.0	123.7	3.3
38	127.2	123.4	3.8
39	127.3	123.1	4.2
40	127.1	123.0	4.1
41	127.5	123.2	4.3
42	127.7	123.2	4.5
43	127.3	123.3	4.0
44	127.9	123.4	4.5
45	128.1*	123.5*	4.6
Gain in C. M.	.7%	0	
Gain in Per Cent	.5%	0	

* Measurement before calving.

PLATE 1

HEIGHT AT WITHERS IN C.M.

GROWTH AS AFFECTED BY LACTATION
AS SHOWN BY HEIGHT AT WITHERS
--- LATE CALVING GROUP
— EARLY CALVING GROUP
* POINTS OF CALVING

127
126
125
124
123
122
121
120
119
118
117
116
115
114

18 19 20 21 22 23 24 25 26 27 28 29 30 31 32 33 34 35

AGE IN MONTHS

CROSS SECTION. 10 x 10 TO 1 INCH.

CROSS SECTION. 10 x 10 TO 1 INCH.

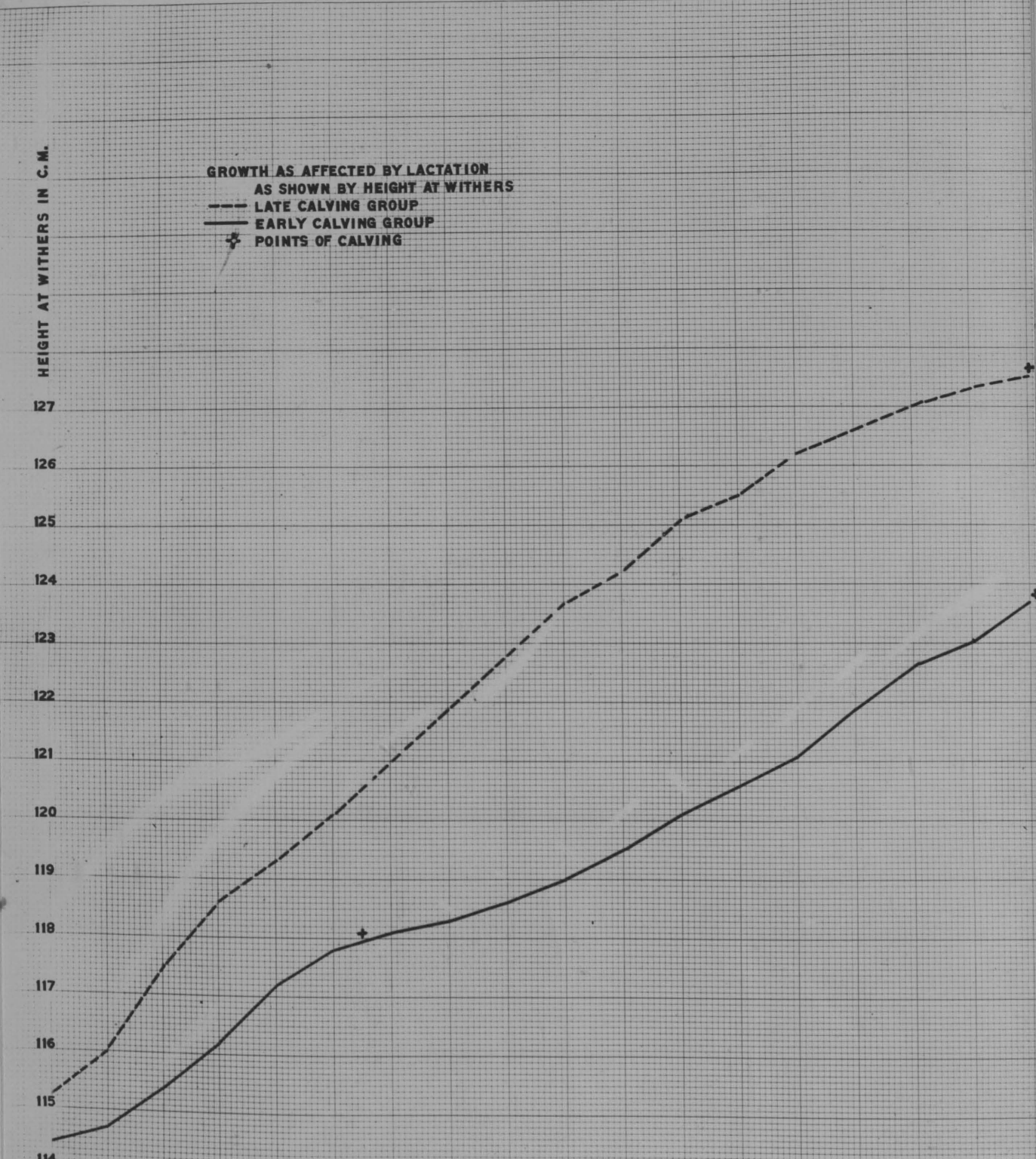


TABLE III.

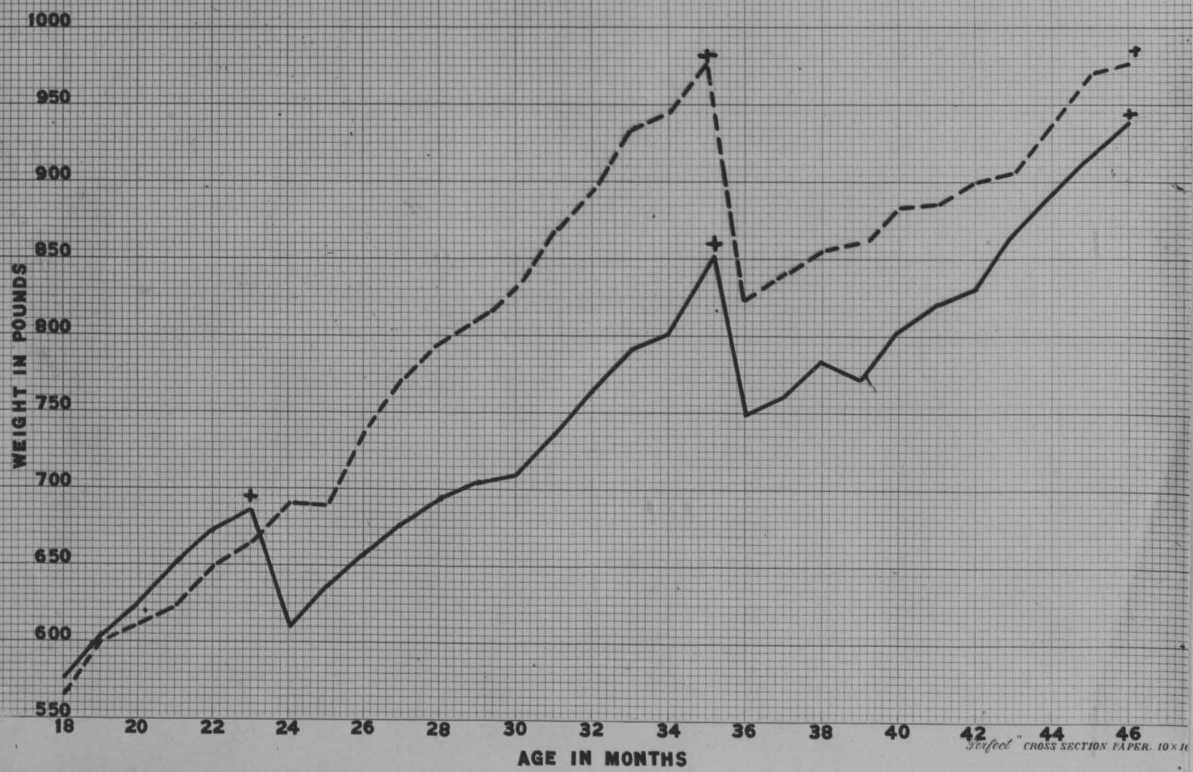
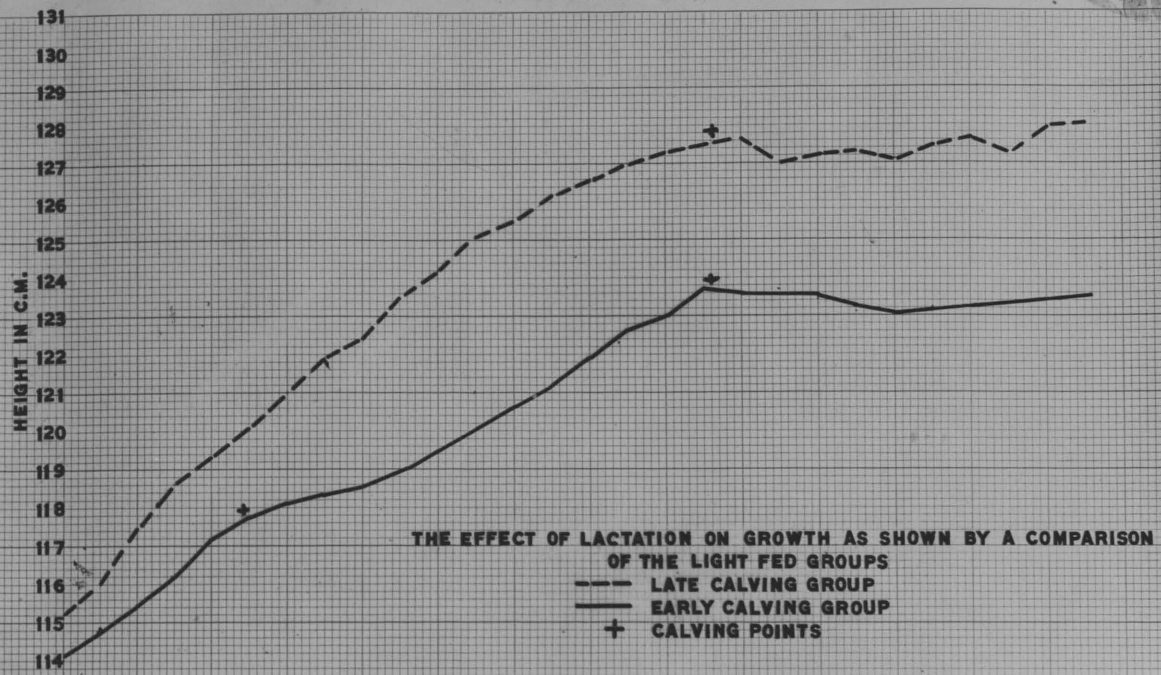
EFFECT OF LACTATION ON GROWTH

Light Fed Late Calving Compared With
Light Fed Early Calving.

Age in: Months:	Body Weights in Pounds		:
	Late Calving	Early Calving	Difference
18	565	576	-11
19	601	604	- 3
20	612	625	-13
21	623	650	-27
22	647	672	-25
23	667	686*	-19
Gain in Pounds	102	110	
Gain in Per cent	18.2%	19.0	
24	690	610	80
25	689	636	63
26	736	657	79
27	771	677	94
28	795	693	102
29	813	705	108
30	832	709	123
31	867	735	132
32	894	769	125
33	932	790	142
34	944	800	144
35	976*	850*	126
Gain in Pounds	309	164	
Gain in Per cent	46.3%	23.9%	
36	823	750	73
37	840	761	79
38	855	784	71
39	863	771	92
40	883	803	80
41	886	821	65
42	900	831	69
43	907	866	41
44	937	892	45
45	970	916	54
46	976*	939*	38
Gain in Pounds	0	89	
Gain in Per cent	0%	10.4%	

*Weight before calving.

PLATE 3



group gained in height at an increasingly slower rate than did the late calving group, until, a year later or 6 months after they had calved the early calving group were 5 c. m. less in height than the late calving group. Thereafter until the calving of the late calving group the early calving cows gained at a slightly faster rate as compared to the late calving group. At the time of calving of the late calving group the early calving group were 123.7 c. m. high while the late calving group measured 127.5 c. m.

The curves in Plate I show quite clearly the difference in the rate of growth of the two groups from the ages of 18 to 36 months. The dotted line representing the growth of the late calving group follows very closely the general trend of the normal growth curve. The rate at which the curve rises gradually decreases throughout its entire length. During the first few months it rises at the rate of about a centimeter per month while in the last few months it shows a rise of less than .3 c. m. per month, a decrease in rate of more than 66%. This corresponds very closely to Minot's conclusion that the rate of growth normally decreases uniformly from birth to old age.

The solid line represents the rate of growth as exhibited by the early calving group. It will be noted that for the first 4 months this curve follows pretty closely the general direction of the course of growth for the late calving group. At the 22nd month, however, there is a distinct slowing in the rate at which the curve rises. This is just two months before calving and the depression in the rate at this time may be due to the development of the foetus.

After calving the curve shows a marked tendency to flatten out and at this time the rate of growth is about .2 c. m. per month. At the same age the other group was gaining at the rate of about 1 c. m. per month. From this time on the rate of rise gradually increased so that during the 34th month the gain was .7 c. m. compared to .2 c. m. the gain of the late calving group for the same month.

For the first 23 months the management of both groups was in every way identical with the exception that the early calving group were pregnant from the 14th month to the 23rd month. After the early calving group calved, its ration was changed but the change was in the direction of being more favorable to growth

as they got more feed and better care than they had previously. In view of the fact I think that we are safe in concluding that the difference in growth between the two groups as above noted is due to the factor of milk production and our answer to the first question is an affirmative one, lactation does affect growth.

Does Growth Affect Lactation?

In order to study this question the milk production of the light fed early calving groups and the light fed late calving group throughout the first lactation period of each was compared to the production of mature cows throughout a single lactation period. Cows were chosen whose lactation periods were about of the same length. The average milk production in pounds for each of the three groups was taken by 10 day periods.

In the mature group which was considered as having the normal milk production, with the factor of growth eliminated, there were 5 Jersey cows. Care was taken to avoid the choosing of exceptionally good or exceptionally poor cows. The light fed early calving

group contained 5 Jerseys and the light fed late calving group contained four Jerseys.

The result of this comparison is shown in Table I and Plate II. The totals of Table II show a marked difference in production between the three groups.

The average total production for the mature group was 6283 pounds, for the early calving group 3689 pounds, while the production for the late calving group fell between the two, being 4811 pounds.

The curves in Plate II show very clearly the difference in general character of milk production between the three groups. In most respects the curves are very similar. For the first 30 days each of the curves shows a well marked rise to the highest point. From this point to the end of the lactation there is a gradual and uniform decline. The curve for the late calving group shows some irregularities but in general it shows a striking resemblance to the other two curves.

The greatest difference between the curves are the height at which they start and the much more rapid decline of those groups which started highest. All three of the curves come together at a common point.

Each of the three groups received practically the same treatment after they calved. And the late and

TABLE I.

THE EFFECT OF GROWTH ON LACTATION

As Indicated by Milk Production

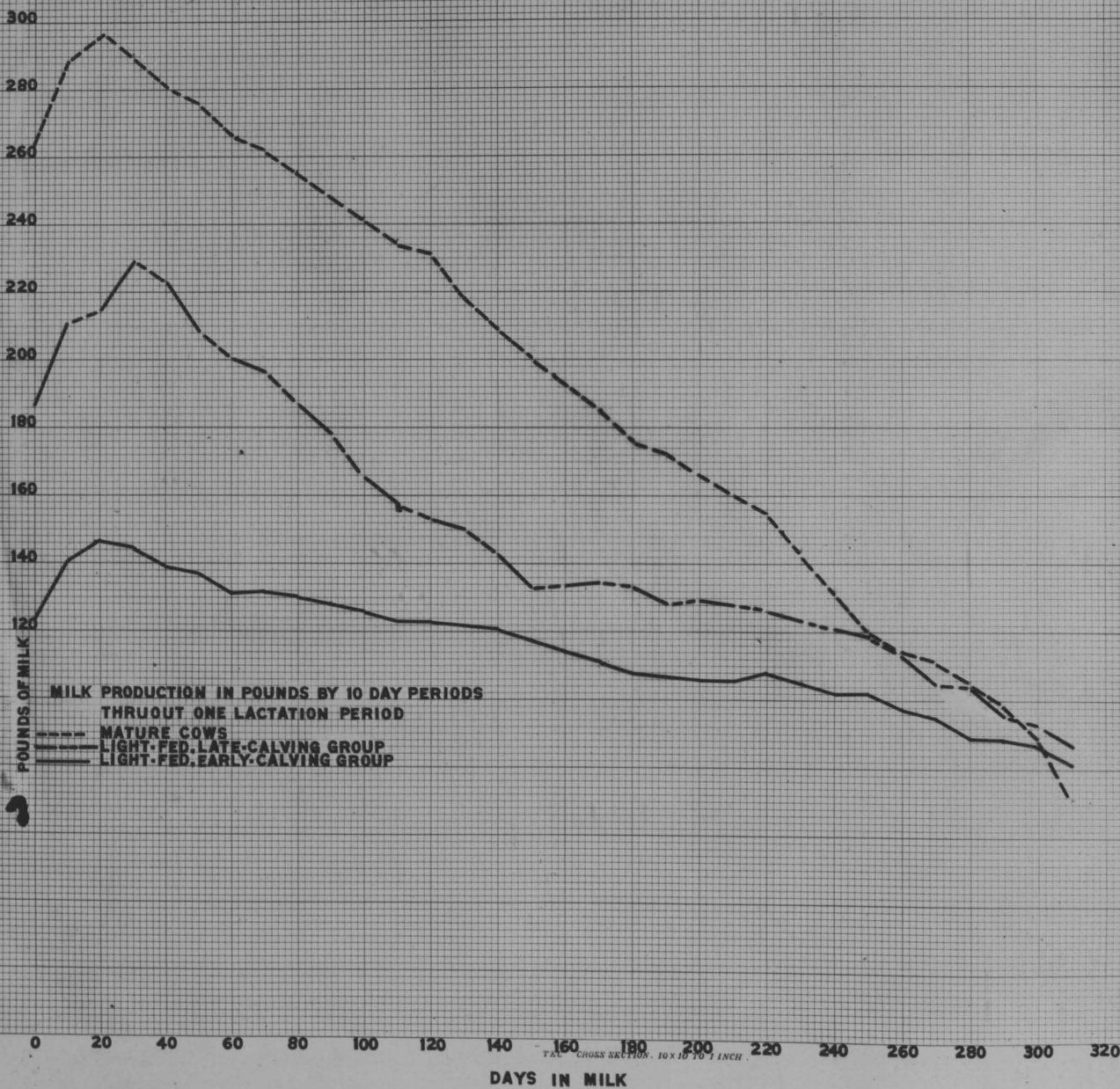
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Production of Light fed groups compared to the production of mature cows by periods of 10 days each.

No. of Period :	Milk Production in Pounds		
	Mature Cows	Early Calving	Late Calving
1	264.0	123.2	186.6
2	288.0	140.2	210.2
3	296.0	146.3	214.7
4	290.5	144.8	228.5
5	277.0	138.9	223.0
6	247.6	136.7	208.3
7	244.7	131.0	200.2
8	247.9	132.0	196.2
9	244.6	130.2	186.4
10	237.9	128.0	179.1
11	232.6	126.1	165.5
12	235.4	123.7	157.7
13	231.2	123.0	153.5
14	218.7	122.0	150.0
15	209.2	120.8	142.9
16	200.4	118.0	132.9
17	192.3	114.0	133.5
18	185.6	111.4	134.8
19	176.4	108.1	133.8
20	173.0	106.3	128.2
21	177.2	106.0	129.7
22	171.9	106.0	128.6
23	174.8	108.0	126.0
24	168.7	105.7	123.6
25	156.0	100.3	123.0
26	138.2	108.2	118.4
27	125.0	90.0	113.2
28	110.6	95.0	104.2
29	105.6	89.0	104.1
30	98.2	88.3	95.1
31	89.1	86.4	92.2
32	74.9	81.4	87.1
Total	6283.2	3689.0	4811.2

PLATE 2

LACTATION AS AFFECTED BY GROWTH



early calving groups received exactly the same treatment before they calved. The age of the mature group ranged from 5 to 7 years at the time of calving, while the early calving group was 24 months of age and the late calving group was 36 months old at the time of calving.

At the beginning of the lactation periods the late calving group weighed 177 pounds more per animal than the early calving group and were 10 c. m. higher at the withers. Weights and measurements were not available on the mature animals, but because of their considerably greater age they were undoubtedly larger than the late calving group.

In each case the older and larger animals gave more milk than the less mature animals. The breeding and care of the animals was too much alike in each of the groups to account for the great difference in production. I think a greater part of this difference must be attributed to the fact that that group which had the least production were the most immature. The demands on the available supply of nutrients was certainly greater with the less mature group leaving less for milk production which may account for it in part. Some of the lack of production may also be due

to the fact that the animals were smaller and because of the undeveloped conditions of their organs, they were unable to consume as much feed and manufacture as much milk as the larger and better developed animals. The answer to our second question is thwn also affirmative, growth does affect lactation.

Which Is The Stronger Tendency In The Dairy
Cow, The Stimulation to Produce Milk or the
Impulse to Grow?

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In the foregoing discussion it was shown that the stimulation to give milk and the impulse to grow were antagonistic forces and that when both were operative as with the light fed calving group each was checked to a certain extent.

The data do not offer any available means of determining exactly how much each was checked. But I think that it does show that the relative strength of each does depend upon the length of time that has elapsed after its initiation. That is with a very young cow the impulse to grow would be much stronger and the stimulation to give milk relatively weaker than with the more mature cow. All the curves of growth show that the younger the animal, the stronger the impulse to grow.

This was borne out in Plate I, with the late calving group the curve was very steep about the 20th month while 16 months later it had almost flattened out. In other words the older the animal the less vitality it has other things being equal.

The same I think is true with the stimulation to produce milk. The nearer the beginning of the lactation period the stronger the stimulation to give milk and consequently the impulse to grow is relatively weaker. Later in the lactation period the stimulation to give milk diminishes in force as shown by the lactation curves. Near the end of the lactation period the stimulation to grow is relatively much stronger. This is borne out by the practical observation that it is almost impossible to "dry off" a good dairy cow when she first freshens while it is a comparatively simple operation six months later.

The curve of the early calving group in Plate I shows this to a remarkable extent immediately after the cow freshened the growth curve shows a tendency to flatten out while later on the rise is much steeper.

Clearly the answer to the above question will depend almost entirely on the length of time that has

elapsed after the stimulus has been imparted to the animal. The younger the animal the stronger the stimulation to grow, the shorter the time after calving the stronger the stimulation to produce milk.

Does the Giving of Milk by an Immature
Heifer Have a Tendency to Permanently
Reduce the Size of the Animal?

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We have seen that lactation in the case of immature animals had a tendency, for a time at least, to check growth. It is a common observation among practical dairymen that when a heifer calves at an extremely early age, she never reaches full size. Our data are not extensive enough to enable us to draw any definite conclusion on the subject. The data cover only two lactation periods for the early calving group and one lactation period for the late calving group.

By comparing the early calving group with the late calving group it is possible to get some idea just how severe an effect early lactation has on size of the animal. While the animals in the light and heavy fed groups calved at the same age, each group was managed differently, and it will be necessary to consider each group separately.

In Tables II and III the growth of the early and late calving divisions of the light fed group are compared. In Table II the height at withers measurement is used to measure growth and in Table III body weight are compared. These tables are shown graphically in Plate 3.

The measurements show the late calving group to be 1.1 c. m. higher at 18 months of age than the early calving group at the same age. Thereafter both groups show a pretty consistent gain up to the 35th month, the time of calving of the late calving group. From the 36th to the 45th month the early calving group showed no gain while the late calving group gained but .5% from which we might conclude that the animals in each group had about reached their maximum height. In the 45th month the early calving group was 4.6 c. m. lower at the withers than the late calving group. Since the animals in the early calving group had apparently ceased to grow it would seem that they were dwarfed to the extent of 3.5 c. m. in height.

However, when we consider that 3.5 c. m. is only about 3% of the total average height of the animals in the group this check in growth is too small to be

of practical importance and might easily be compensated for by an increased rate of growth at some later time when conditions are more favorable.

A glance at Table III in which the body weights are compared shows the same general tendency as indicated by the measurements. In the 18th month the later calving group were 11 pounds lighter than the early calving group and at the end of the 35th month they were 126 pounds heavier than the early calving group. That most of this gain in weight is due to the laying on of body fat by the better nourished group I think is shown by the fact that as soon as the late calving group came into milk most of this weight was lost. This loss was due to the milking off of the fat. At the end of the 46th month the animals of the two groups were gradually approaching the same weight, a difference of 38 pounds in favor of the late calving group being too small to be considered as of importance.

From the above discussion it would appear that the early calving in the case of the light fed animals has a tendency to permanently check the growth slightly or to considerable delay animals reaching their maximum size.

TABLE IV.

EFFECT OF LACTATION ON GROWTH

Heavy Fed Late Calving Compared With
Heavy Fed Early Calving.

Age in Months:	Height at Withers in C. M. : Late Calving :	Early Calving:	Difference
18	119.8	121.1	-1.3
19	120.9	121.6	- .7
20	121.4	122.1	- .5
21	122.1	122.5	- .4
22	122.6	122.9	- .3
23	123.2	123.3*	- .9
<hr/>			
Gain in C. M.	3.4	1.2	1.3
Gain in Per cent	2.8 %	.9	1.1
<hr/>			
24	124.1	123.7	1.83
25	124.9	123.8	1.1
26	125.1	124.3	1.8
27	125.6	124.5	1.1
28	125.9	124.8	1.1
29	126.0	125.1	.9
30	126.4	125.5	.9
31	126.7	126.2	.5
32	127.8	127.8	1.0
33	127.1	127.6	.5
34	127.4	127.1	.3
35	127.6*	127.1*	.5
<hr/>			
Gain in C. M.	4.4	4.8	
Gain in Per cent	3.5 %	3.8	
<hr/>			
36	127.7	127.8	- .1
37	127.8	128.2	- .4
38	127.3	128.2	- .9
39	127.4	128.4	-1.0
40	127.8	128.4	-1.1
41	127.7	128.8	-1.1
42	127.7	128.8	-1.1
43	128.5	128.7	- .2
44	128.3	128.9	- .6
45	128.1*	128.7*	- .6
46			
<hr/>			
Gain in C. M.	.5	1.6	
Gain in Per cent	.39	1.2	
<hr/>			

* Measurement before calving.

TABLE V.

EFFECT OF LACTATION ON GROWTH

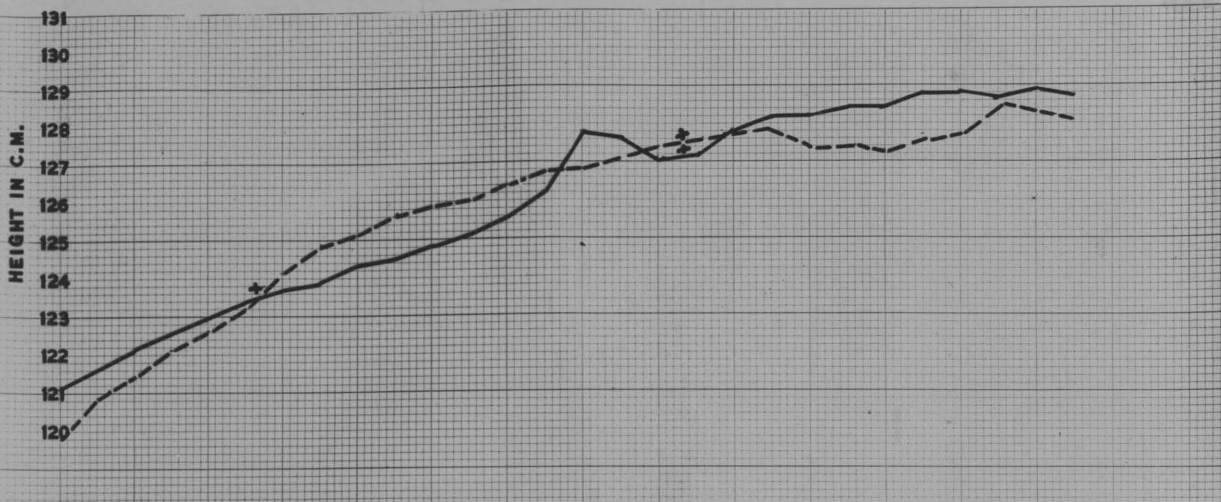
Heavy Fed Late Calving Compared With
Heavy Fed Early Calving.

Age in Months:	Body Weights in Pounds		
	Late Calving:	Early Calving:	Difference
18	725	716	9
19	759	759	0
20	793	799	-6
21	823	829	-6
22	837	863	-26
23	859	891*	-32
<hr/>			
Gain in Pounds	134	17.5	
Gain in Percent	18.3 %	24.4 %	
<hr/>			
24	872	817	55
25	891	806	85
26	913	791	122
27	931	800	131
28	948	793	155
29	960	803	157
30	974	832	142
31	1009	853	156
32	1032	886	146
33	1052	903	149
34	1070	934	136
35	1096*	957*	139
<hr/>			
Gain in Pounds	237	66	
Gain in Percent	26.4 %	7.4 %	
<hr/>			
36	952	863	89
37	940	872	68
38	933	848	85
39	932	880	52
40	944	913	31
41	941	898	43
42	929	926	3
43	916	943	-26
44	966	994	-28
45	970	1003	-33
46	1035*	1043	- 8
<hr/>			
Gain in Pounds	-61	86	
Gain in Per cent	- 3.5 %	8.9 %	

*Weight before calving.

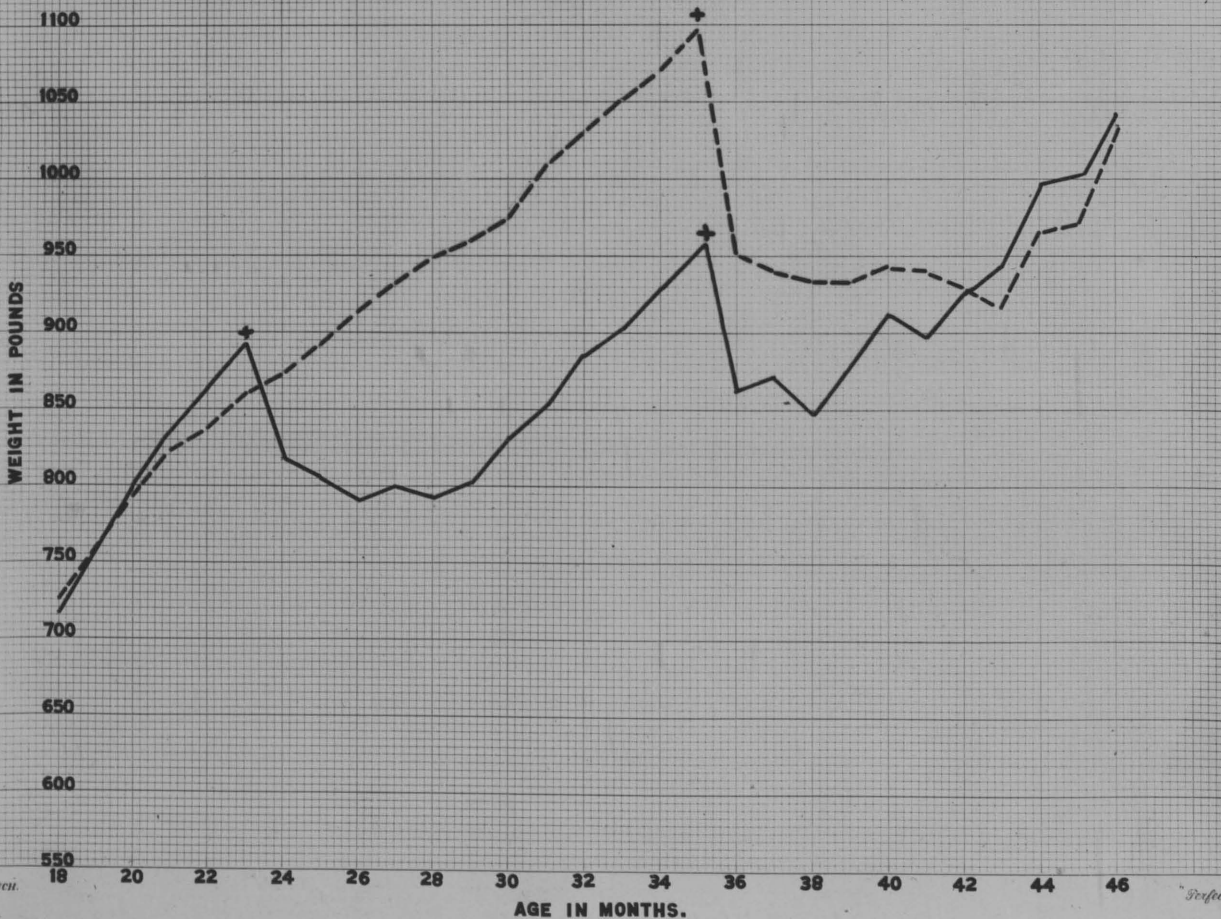
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PLATE 4



THE EFFECT OF LACTATION ON GROWTH AS SHOWN BY A COMPARISON OF THE HEAVY FED GROUPS.

--- LATE CALVING GROUP.
— EARLY CALVING GROUP.
+ CALVING POINT.



1920

Profed

A consideration of the heavy fed group, Tables IV and V and Plate 4, does not bear out the results as shown by the light fed group. Both early and late calving divisions were practically the same size at 18 months and 46 months of age. The explanation of this lies probably in the fact that though the animals were exactly the same age those of the heavy fed group were much more mature than those of the light fed group.

The importance of the factor of the plane of nutrition on the ultimate size of the animal may be studied by a comparison of the early calving light fed group with the early calving heavy fed group, and by likewise comparing the late calving group.

Tables VII and VI and Plate 5 shows the results of the comparison of the early calving group. Table VI compares growth as indicated by height at withers measurements, while Table VII gives a comparison of the body weights. Practically the only difference between these groups being that of the plane of nutrition previous to calving.

TABLE VI.

EFFECT OF THE PLANE OF NUTRITION ON GROWTH

Late Calving Groups Compared.

Age in: Months:	Pounds		:
	Heavy Fed	:	Light Fed :Difference
18	725		565 160
19	759		601 158
20	793		612 181
21	823		623 200
22	837		647 190
23	859		667 192
<hr/>			
Gain in Pounds,	134		102
Gain in Per Cent,	18.3 %		18.0 %
<hr/>			
24	872		690 182
25	891		689 202
26	913		736 197
27	931		771 160
28	948		795 153
29	960		813 147
30	974		832 142
31	1009		867 142
32	1032		894 138
33	1052		932 120
34	1070		944 126
35	1096*		976* 120
<hr/>			
Gain in Pounds,	371		41.1
Gain in Per Cent,	51.1 %		72.7 %
<hr/>			
36	952		823 129
37	940		840 100
38	933		855 78
39	932		863 69
40	944		883 61
41	941		886 55
42	929		900 29
43	916		907 9
44	966		932 29
45	970		970 0
46	1035*		976* 58
<hr/>			
Gain in Pounds	-61		0
Gain in Per Cent	- 5.5 %		0

* Last weight before calving.

TABLE VII.

EFFECT OF THE PLANE OF NUTRITION ON GROWTH

Early Calving Groups Compared

Age in Months :	Pounds		Difference
	Heavy Fed	Light Fed	
18	716	576	140
19	759	604	155
20	799	625	174
21	829	650	179
22	863	672	191
23	891*	686*	205
<hr/>			
Gain in Pounds,	175	110	
Gain in Per Cent,	24.4 %	19.0 %	
<hr/>			
24	817	610	207
25	806	636	170
26	791	657	134
27	800	677	123
28	793	693	100
29	803	705	98
30	832	709	123
31	853	735	118
32	886	769	117
33	903	790	113
34	934	800	134
35	957*	850*	107
<hr/>			
Gain in Pounds,	66	16.4	
Gain in Per Cent,	7.4 %	23.9 %	
<hr/>			
36	863	750	113
37	872	761	111
38	848	784	64
39	880	771	101
40	913	803	110
41	898	821	77
42	926	831	95
43	943	866	77
44	994	892	102
45	1003	916	87
b 46	1043*	939*	104
<hr/>			
Gain in Pounds,	86	89	
Gain in Per Cent,	8.9 %	10.4 %	

* Last weight before calving.

PLATE 5

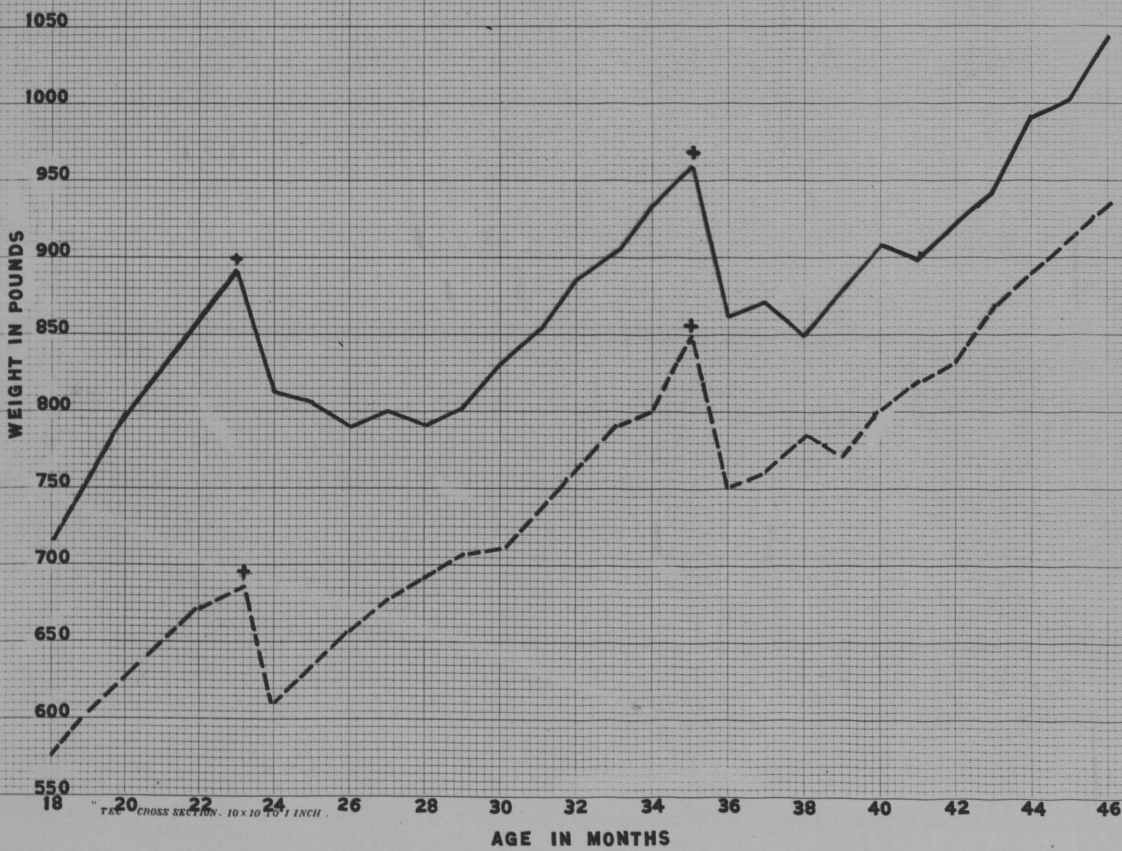
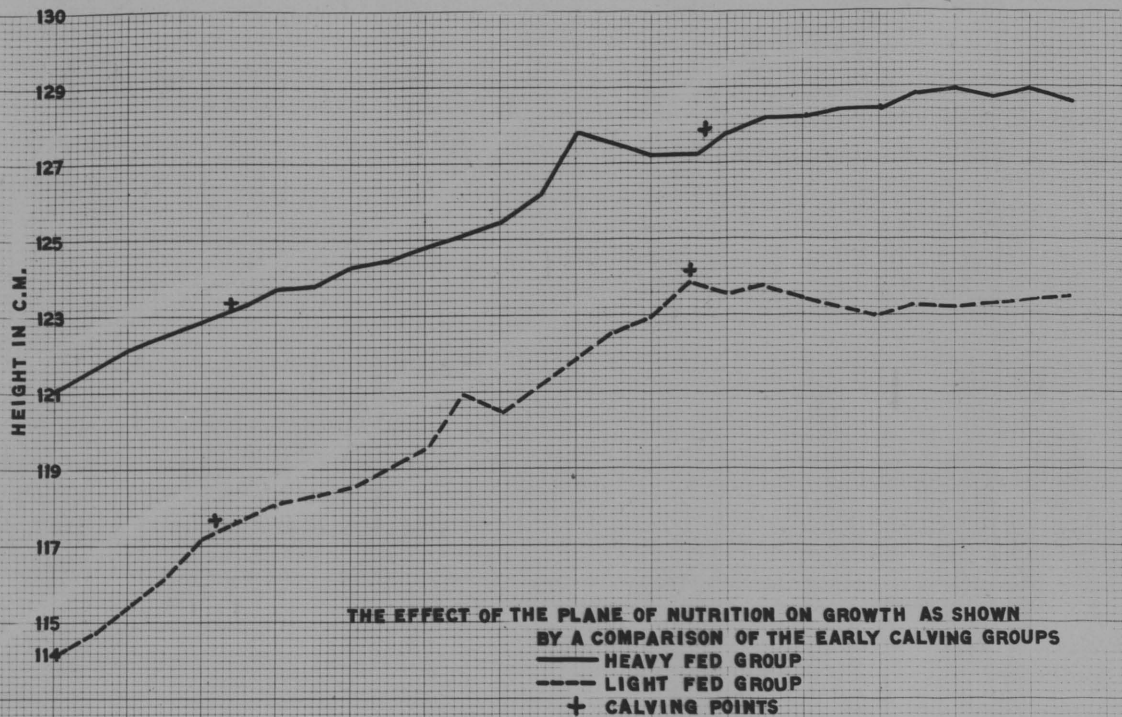


TABLE VIII.

EFFECT OF THE PLANE OF NUTRITION ON GROWTH

Late Calving Groups Compared

Age in Months:	Height at Withers in C. M.		Difference
	Heavy Fed	Light Fed	
18	119.8	115.2	4.6
19	120.9	116.0	4.9
20	121.4	117.5	4.1
21	122.1	118.6	3.5
22	122.6	119.3	3.3
23	123.2	120.1	3.1
Gain in C. M.	3.4	4.9	3.1
Gain in Per Cent,	2.8 %	4.2 %	3.
24	124.1	121.0	3.1
25	124.9	121.9	3.0
26	125.1	122.4	2.7
27	125.6	123.5	2.1
28	125.9	124.2	1.7
29	126.0	125.1	.9
30	126.4	125.5	.9
31	126.7	126.2	.5
32	126.8	126.6	.2
33	127.1	127.0	.1
34	127.4	127.3	.1
35	127.6*	127.5*	.1
Gain in C. M.	4.4	7.4	
Gain in Per Cent,	3.5 %	6.1 %	
36	127.7	127.7	.0
37	127.8	127.0	.8
38	127.3	127.2	.1
39	127.4	127.3	.1
40	127.3	127.1	.2
41	127.7	127.5	.2
42	127.7	127.7	.0
43	128.5	127.3	.2
44	128.3	127.9	.4
45	128.1*	128.1*	0.0
Gain in C. M.	.5	.7	
Gain in Per Cent,	.39 %	.5 %	

* Last measurement taken before calving.

TABLE IX.

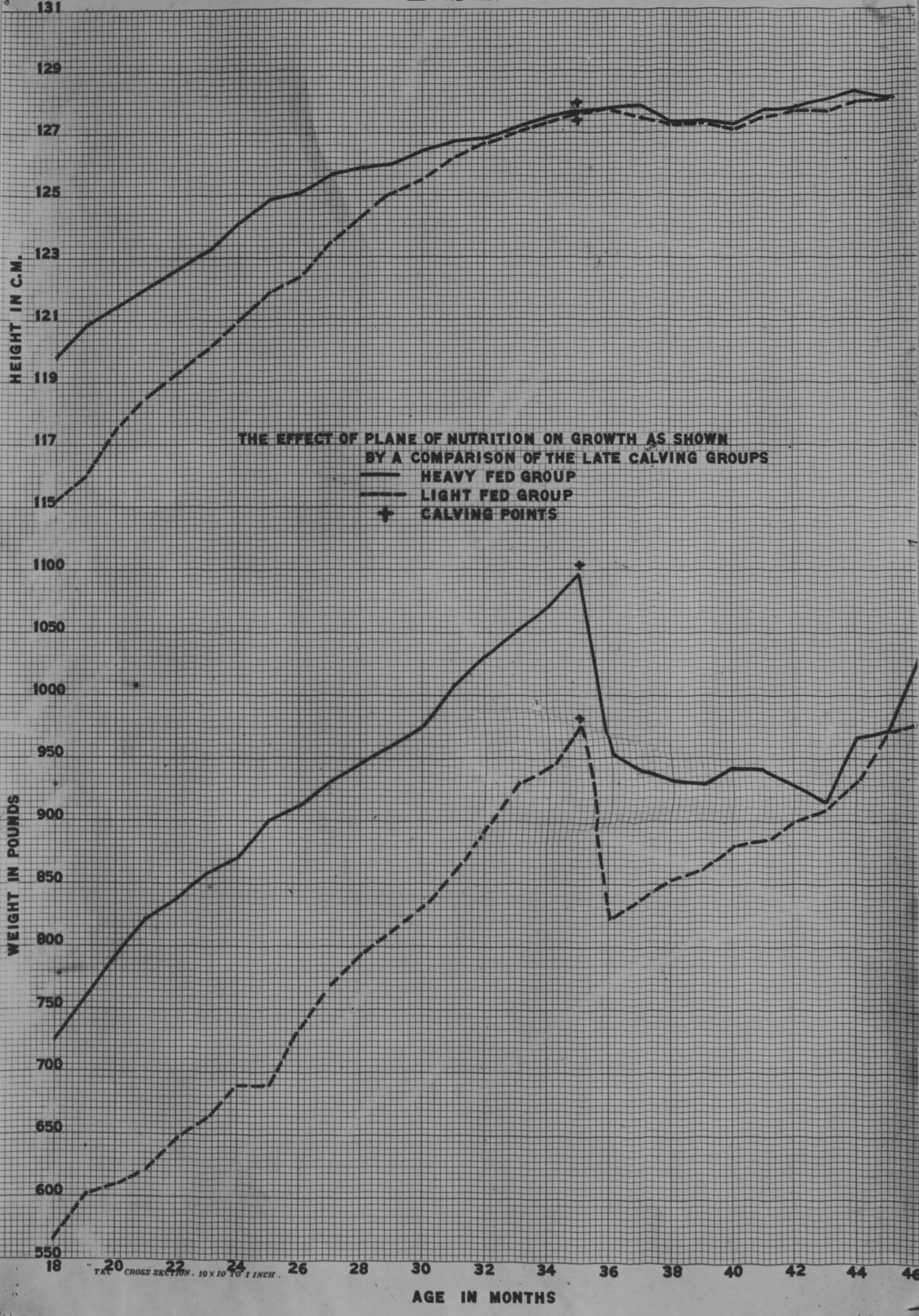
EFFECT OF THE PLANE OF NUTRITION ON GROWTH

Early Calving Groups Compared

Age in Months :	Height at Withers in C. M. :		Difference
	Heavy Fed	Light Fed	
18	121.1	114.1	7.0
19	121.6	114.7	6.9
20	122.1	115.4	6.7
21	122.5	116.2	6.3
22	122.9	117.2	5.7
23	123.3*	117.7*	5.6
<hr/>			
Gain in C. M.	1.2	3.6	
Gain in Per Cent,	.9 %	3.1 %	
<hr/>			
24	123.7	118.1	5.6
25	123.8	118.3	5.5
26	124.3	118.5	5.8
27	124.5	119.0	5.5
28	124.8	119.5	5.3
29	125.1	121.0	5.0
30	125.5	120.6	5.1
31	126.2	121.1	5.1
32	127.8	121.9	6.1
33	127.6	122.6	5.0
34	127.1	123.0	4.1
35	127.1*	123.7*	3.4
<hr/>			
Gain in C. M.	4.8	6.0	
Gain in Per Cent,	3.8 %	4.8 %	
<hr/>			
36	127.8	123.6	4.2
37	128.2	123.7	4.5
38	128.2	123.4	4.8
39	128.4	123.1	5.3
40	128.4	123.0	5.4
41	128.8	123.2	5.6
42	128.8	123.2	5.6
43	128.7	123.3	5.4
44	128.9	123.4	5.5
45	128.7*	123.5*	5.0
<hr/>			
Gain in C. M.	0	0	
Gain in Per Cent,	0	0	

* Last measurement taken before calving.

PLATE 6



The results of this comparison shows that the light fed group is considerably smaller as shown by weight and measurement. There is little tendency shown for the light fed group to approach the heavy fed group in size.

This result is not borne out by the comparison of the light fed late calving and the heavy fed late calving groups. As shown by Tables VIII and IX and Plate 6, the animals in the two groups approach the same size very rapidly, after calving and soon the light fed group is as large as the heavy fed group.

From this it would seem that the greatest effect on the size of the animal comes when we have early lactation and light feeding combined. With animals bred to calve late or with animals well nourished previous to calving there is little danger of dwarfing the animal.

Conclusion.

From the above data and discussion only conclusions of a very general nature can be drawn. The data do not cover a long enough period of time and

the conditions are not extreme enough. To draw definite and specific conclusions upon this subject it would be necessary to keep a number of cows on a low nutritive plane and to take data on them throughout their entire lives. By breeding these animals as early as possible and thereafter as often as possible in order to keep up a continuous milk flow it would be possible to determine pretty accurately the effect of lactation on growth and also the effect of growth on lactation.

From the data here presented it is possible to conclude that:

1. Lactation does affect growth.
2. Growth does affect lactation.
3. The relative amount of the effect of each depends upon the length of time that has elapsed since the beginning of each.
4. The more immature the animal at the time of lactation the greater is the check on growth, and the more tendency there is for the check to be a permanent one.



This thesis is never to leave this room.
Neither is it to be checked out overnight.

