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FACTORS AFFECTING THE GROWTH OF DAIRY ANIMALS

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OUTLINE

FACTORS AFFECTING THE GROWTH OF DAIRY ANIMALS.

INTRODUCTION

Since prehistoric times, domestic animals have been closely associated with the development of the human race. In early times the growth of animals was taken as a matter of course and its observation attracted little attention. As time advanced it became noticeable that environmental conditions seemed to have an effect upon animal development, and men with scientific minds began to theorize concerning the phenomena and underlying causes of growth, so that the consideration has become one of the greatest problems of science.

A consideration of the dairy industry alone in the United States, indicates that, assuming the average period of production for a dairy cow to be five years, 4,000,000 cows must come to maturity each year in order to maintain the total number which is given by census figures as at least 20,000,000. As cows do not ordinarily begin to return an income before they are two years of age, the necessary number of immature and unproductive dairy heifers on hand must be at least 8,000,000. The feed-cost for raising a dairy heifer to the time of first calving has been estimated at from $40 to $50. The problem, then, of raising a sufficient number of heifers to maintain the supply of dairy cows, is one of great importance.

All successful breeders are continually striving to improve the quality of their herds. The value of any dairy herd is determined to a great extent by the way in which the heifers within that herd have been raised and developed, and for this reason the problem of determining the growth-regulating factors is one of great importance from a practical standpoint.

GROWTH

What is growth? That is one of the questions which scientists the world over are trying to answer at the present time. Mendel[53] considers growth as "the resultant of an inherent growth impulse - an internal factor - and a suitable environment; the latter including the food supply - an external factor". Attempts to define the term have in almost every case been unsatisfactory so that today, with scientists spending their lives in the attempt to solve the mysteries of growth, hardly an adequate definition exists. Mendel realized this fact when he said, "There is no satisfactory definition of growth" and "It is probably impossible to define it".[53] Even tho a satisfactory definition is lacking, the word 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.

Although the knowledge of these phenomena is meagre, the most common thing in the world is growth. Not only does it confront us at every turn but it is the agency by which we are given the possibility of developing from mere masses of protoplasm into the highly complicated human animal - man.

Growth and life can hardly be separated - the two go hand in hand. Growth for an individual begins simultaneously with the life of that individual at the moment the egg of the mother unites with the sperm of the father. With this union is imparted a stimulus which, together with inheritance, forms a foundation upon which is based not only many of the problems of agriculture, but the maintenance of the human race.

The "inherent tendency" is fundamental. The part which nutrition plays is secondary. "The rhythm of cell division called 'Wachstum-potential' by Escherich, is limited for every class of animals and for every individual, therefore, even with the greatest intake of food, growth will never exceed a certain limit".[3] "Nutrition, which is often looked upon as a controlling factor, can do no more than give free scope to the inherent

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tendency to grow".[53] This cannot be altered. Not only do these two factors exist, but growth is further complicated by a large number of other factors which will be considered later.

Mendel[53] has inferred that all growth, whether it be of the cells, tissues or organs must be due to:-

1. Multiplication or division of cells.
2. Enlargement of cells.
3. Deposition of intercellular material.

According to Donaldson[7], "The constituent cells of the body enlarge, divide, and in turn enlarge, at the same time that some of them cease to divide further. The number of these latter cells increases rapidly, while the relative number of the dividing cells diminishes". Thus "growth like reproduction involves cell-division. As a mass of living substance increases, the cells must multiply, for every cell has assigned to it a limit beyond which it cannot pass. Cell-division goes on, though with gradually decreasing frequency throughout practically the whole of life; tissue-formation continues but from an early period of development onward, there is a progressive diminution in the power of growth. Increase in the number of cells is, however, specially characteristic of the embryonic period. In the latter stages of development growth occurs largely through cell-enlargement and the deposition of intercellular substance".[38a]

In reference to Minot's comparison to "wall-building" Boveri[38a] has enunciated the general law that cell-division is regulated by the proportion of chromatin to cytoplasm and that it ceases when the ratio of the mass of chromosomes to that of the cells in any tissue or organ reaches a certain definite point, and that the size of the cells of any given tissue after active cell multiplication has ceased, bears a definite ratio to the original mass of chromatin in the fertilized egg.

NORMAL GROWTH.

The "inherent tendency" for growth in individuals has been emphasized. Variations occur in all characteristics with every class of animals and the growth characteristic is no exception. A normal value for a given species can be derived then, only from taking averages of large numbers of apparently normal animals within that species. In this way wide variations will be smoothed out by the balancing effect which one variation will have on another variation in the opposite direction.

At present normal values are available for many species of animals. The most satisfactory values for dairy animals are those calculated by Burlingham and Gillette.[9]

"The growth of the cow in weight continues for at least two years after the skeleton stops growing. A Jersey cow, well-fed when young, is practically mature in frame at three years but increases in weight up to the age of five or six years. Holsteins on the average grow a little in skeleton between the ages of four and five years but increase in weight regularly up to six or even seven years".[9]

Normals have been calculated for humans and many of the lower animals and C. M. Jackson[35] experimented with white rats to learn as much as possible of the phenomena of growth, and to determine the limits of normal variation.

POST NATAL LOSS IN WEIGHT

A subject which deserves consideration at this point is the loss which is experienced in all animals immediately after birth. Dr. Minot[56] mentions it in his study of guinea pigs and T. Brailsford Robertson[84] writes that the majority of infants lose weight for a few days after birth. This, he says, is true of other animals and is sometimes attributed to lack of nutrition with children.

Robertson concludes essentially that:-

1. It is a tendency for infants of long gestations to lose most heavily.
2. The size at birth is closely related to the subsequent loss.
3. The retardation is suffered by both males and females.
4. There is more variation in male than in female retardation.
5. The subsequent compensatory acceleration is more pronounced in the female than in the male.

To quote Minot,[56] "Male guinea pigs lose weight as do newborn children for a variable period of a few days after birth". In both sexes, the weight is retarded at birth but much more in the male than in the female, so much in fact, that there is an actual loss.

VARIATION AND INDIVIDUALITY.

Individuality is the one word which may be used in summarizing the results obtained on an experiment at the Georgia Agricultural Experiment Station,[14] and individuality at once suggests variation. The coefficient of variation is used to represent variability in animals. It is one-hundred times the ratio which the standard variation bears to the mean.

$$\sigma = \frac{\sqrt{\Sigma d^2}}{n} \quad \text{and} \quad C = \frac{\sigma}{a} 100$$

The coefficient for British-American humans at birth has been given as 15.7 for the male and 14.2 for the female. Porter,[35] from thousands of observations on weights of school children in St. Louis has determined the relative coefficients for males and females at the different ages. His figures compare favorably with those given by Pearson[35] and Schuster[35] who worked in England. Figures on white rats show the greatest coefficient at twenty days. On the grounds of the work performed Porter, Thoma and Boas[35] have all concluded that variation is correlated with rapidity of growth except in the case of some newborns, when the growth is more rapid. It is noticed that in humans the greatest variability occurs at the time of puberty when abnormal gains occur. Figures for rats show results similar to those for the higher animals.

FRATERNAL VARIATION.

In 1894 Galton[35] found the average stature of man to be 68.2 inches with a probable deviation of 1.7 inches. He found that with brothers the deviation was only 1.06 inches or 62 percent of the racial variation. Later calculations set the figure at 87 percent. Intra-litter rats varied in body weight less than half as much as the general population. Of course intra-litter and fraternal variations are not exactly comparable. At any rate, all things emphasize the importance of individuality and of inheritance in growth.

THE MEASUREMENTS OF GROWTH.

It will be noted that while some stature measurements have been used in showing human growth, the majority of conclusions have been based upon weights. This is unfortunate because weight alone cannot satisfactorily represent growth. Weight and skeletal growth seem to a great degree independent of each other. Mendel has emphasized the need of some means of ascertaining and measuring growth but shows its difficulty on account of uncorrelated increments, such as depositions of material in humans in middle life. It has been written of Hans Aron[2], "From his experiments the author concludes that the force which he calls "growth tendency" is more noticeable in the skeleton than in other parts of the body. If an animal fasts the skeleton grows at the expense of the rest of the body; the fatty tissues being used first, and the other organs later, since the more important organs are also the more resistant. In his opinion the force that induces growth is resident in the skeletal frame-work, the muscular tissue possessing apparently no specific "growth tendency"; but, perhaps owing to mechanical forces, following the skeleton in its growth, provided the nutrition is sufficient to permit it." It is possible for an animal to grow in height and remain at constant weight, or in more severe cases even to lose in weight.

Nearly forty years ago an attempt was made to measure growth by metabolism, and Carl Voit[52] in 1881 published a monograph in which he gave expression to the prevailing belief of the time which was that the growth period was characterized by a relatively large food requirement and "intensity of metabolism."[52] He writes, "It is generally believed that the youthful organism is the seat of a particularly active metabolism."[52] At that time little was known of energy features but the metabolism idea centered in the metabolic changes in nitrogenous compounds. Voit realized and noted that flesh-deposition is possible in the adult but that the tissue increment phenomenon in the animal during the growing period is much more noticeable.

Commonly it is supposed that an animal grows slowly at an early age, but increases more rapidly as age advances. At present, figures are available which prove that this conception is erroneous. There are different ways of expressing growth. Growth itself may be represented by the amount of the increments within certain periods of time, but whether or not the rate of growth can be shown in this way depends upon the point of view. It may or may not be more satisfactory to show the rate by the percentage increment of each period over the preceding weight or measurement. By this method of representation an animal weighing 1000 pounds and gaining 4 pounds a day is not growing at such a rapid rate as one weighing 200 pounds and gaining one pound a day. The method of representation should vary according to circumstances and should not be limited to one basis.

For satisfactory measurements of growth, at least two things must be considered - weight and skeletal measurement. Methods of taking the skeletal measurements of cattle will be considered.

THE LIMITS OF GROWTH.

The cause of the cessation of growth is not known. Morgan[58c] believes that it is due to an inhibitory factor which limits growth. In confirmation of this idea he considers the regeneration of the tail of a salamander. When a salamander's tail is cut off near the tip it grows much more slowly than when cut nearer the base. Regeneration seems to follow normal growth and an inhibition seems to take place when a certain size is reached. The same is true of an earthworm to a more pronounced degree. When an earthworm's tail is removed near the tip, regeneration is slow, while if cut near the middle it is rapid.

Insufficiency of food will result in checking or stopping growth but this is an abnormal condition.

Minot[38c] believes that senescence, which is the passage from youth to old age, is due to "an increase in the differentiation of the protoplasm". He states that 'during the early periods of life the young material is produced and the protoplasm is undifferentiated. During the later stages of existence all the differentiation goes on, and the organism gradually becomes old. When the cells acquire the faculty of passing beyond the simple stage to the more complete organism they lose something of their vitality, of their power of growth, and of their possibilities of perpetuation'.

It is not known whether an animal ceases to grow because a natural inhibitory factor develops or because the animal loses its stimulus for growth. Mendel[53] shows that the power of regeneration diminishes as the vertebrate scale is ascended and attributes the fact chiefly to the lack of coördinate regeneration in the higher vertebrates. The power seems to be present in all human tissues but in different degrees so that coördination cannot exist. May not the one fundamental cause be differentiation of the cells of the various tissues, and may not this one word - differentiation - represent the cessation of growth?

According to Minot[57a] 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 can grow as much as 1000 percent in a day, and that over 98 percent of the loss in growth-rate is reached before birth. An animal, then, begins ex-uterine life with less than 2 percent of the original growth power with which it was endowed. For the human embryo it is estimated that from impregnation to the end of the first month an increase of over one million percent has taken place. Minot compares growth with a man building a wall. The wall goes up rapidly at first but as the wall becomes higher the work progresses more slowly till finally the man becomes tired and stops - the limit is reached.

A similar idea is expressed by Marshall[38a] who believes that growth and tissue formation continue through life, but at a constantly diminishing rate.

It has been suggested that "the reason why the animal ceases at length to grow, is not because there is a necessary limit to growth-force at a certain distance from impregnation, but because it is in the nature of the species that the individual should cease to grow at this point".[7]

Ferry[7] finds in working with rats that it is size rather than age which determines the rate of growth.

The conclusions of Minot[57] are that "though protoplasm is the physiological basis of life, though it is the actual living substance of the body, its undue increase beyond the growth of the nucleus changes the proportions of the two and that change in proportion seems to cause an alteration in the condition of the living cell itself, and that alteration I interpret is the cause of senescence as the fundamental cause of old age".

In summarizing the work it would seem that Kellicott[36] is nearer the solution of the problem than any other when he writes, "It seems quite 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 through inhibition or acceleration and the effect produced may be due either to the presence or the withdrawal of the specific substance".

HORMONES AND THE DUCTLESS GLANDS.

Hormones or "chemical messengers" are responsible for large numbers of the involuntary physiological functions. It has been assumed that such may be the cause of growth-stimulation as has been so nicely stated by Kellicott in the preceding paragraph.

The fact is proven that the removal of certain glands produces a poor physiological condition, cessation of growth and even death, and that feeding the extract of the corresponding gland of another animal causes rapid recovery, and a resumption of growth. Such facts indicate the probability that those glands secrete a "something" which is responsible, either directly or indirectly, for the phenomena of growth.

Of the ductless glands the thyroid has been called the "dean". Goitre in humans is a condition in which the thyroid is enlarged. In severe cases the development of those affected persons known as cretins, is completely arrested and they become idiotic dwarfs.

The enlargement of the pituitary body, a small gland in the center of the base of the skull, causes an enlargement of the osseous extremities and makes a "caricature of the human shape". When the gland enlargement occurs in childhood a uniform overgrowth takes place resulting in a giant. It has been shown that dwarfs have an abnormally small pituitary. In some cases the feeding of animal pituitary has caused a decided improvement and the author[34] states ----"the gland appears to be a sort of growth - or - stature - regulator for the skeleton of the body."

The pineal body lies almost in the center of the brain and is found to have a considerable influence upon the development of the body; its removal being followed by an entire arrest of growth. Young animals fed upon pineal extract grow more rapidly and attain maturity earlier than those not receiving the extract.

According to Hutchinson[34] the thymus seems to be associated with growth in young animals. After growth is well under way, however, its removal will have no ill effects. Paton and Goodall,[80] on the contrary, find "that the removal of the thymus, even on the day of birth, has no effect on the rate of growth of guinea pigs".

ANIMALS USED FOR EXPERIMENTAL WORK.

Experiments have been carried on chiefly with laboratory animals such as albino rats and guinea pigs. The reasons for their use are:-

1. They are easily reared and cared for.
2. The food requirement is small.
3. The life of the rat is 3 years - consequently one year represents a long period of the life of the higher animals.

4. Other investigations have been with these animals and normal standards are available.

Laboratory animals are adapted to use in a preliminary study of growth, but the results obtained with them cannot be considered as applicable to all species unless similar results are obtained with the higher animals. A disadvantage in their use is the fact that their skeletal growth cannot be satisfactorily measured, and body weight must be used as an index.

Aron experimented with dogs, and others have gone a step farther and have taken data on humans. Much work has been done with humans in France, Pearson[35] took data on newborns and on Cambridge University students to determine normals and coefficients of variation, and Schuster[35] took similar data on Oxford students. In this country Beyer[4] took measurements on over 4000 naval cadets and Porter[35] compiled a table of figures from the school children of St. Louis. Similar ones are available from children in Boston.

Data on domestic animals have been collected only in recent times. Laws have been formulated which hold within a species, but probably the laws of any one cannot be said to hold for all species. While data are avilable on the growth of man, the cow, horse, sheep, dog, rat and guinea pig[7] it is interesting to note that man stands alone in regard to the percent of energy required for growth, while all other animals are alike in this respect. In man only 5 percent of the calories are used for growth, while in lower animals an average of 34 percent is used.

In order that the theories which have been derived from the work with laboratory animals might be made of more practical value, H. J. Waters, at that time Director of the Agricultural Experiment Station at the University of Missouri, began a series of systematic experiments with domestic animals. His experiments have been continued and similar work has been taken up at other Agricultural Experiment Stations, and valuable data are available. The results which have been obtained with domestic animals compare, on the whole, very favorably with those of the laboratory animals.

GROWTH UNDER ADVERSE CONDITIONS.

The "growth tendency" undoubtedly lies

within the skeleton more than within the tissues . "The upper limit of the size of an animal is determined by heredity. The stature to which an animal may actually attain, within this definitely fixed limit is directly related to the way in which it is nourished during its growing period"[91]. Waters takes a strong stand against some theories concerning the rate and uniformity of growth and says, "Some of our approved theories have been so extreme as to hold, in effect, that the animal must grow at its maximum rate practically every day from birth to complete maturity in order to reach its normal size or the full stature fixed by heredity ----. This assumes 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 in the slightest degree, the growth-cycle, much less by growing for a time at least when so sparsely fed that no gain in weight occurs."

"An animal does not seem to grow regularly but rather by small 'spurts and jerks'. On the whole, however, there is a tendency toward a normal rate of growth, which rate even adverse conditions

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do not seriously interfere with, unless carried to extremes."[11]

When an animal grows excessively fast for a period, there follows a period of slower growth and vice versa, those that fall behind make up the loss if they remain in health. It is often noticed that a severe illness is followed by an excessive growth which apparently more than compensates for the loss sustained. At present all will agree that some compensation occurs, but whether or not it is ever complete is questionable.

In experiments of many kinds it has been customary to keep, or attempt to keep, the animals on maintenance. Maintenance has been loosely used as representing a condition of constant weight. This conception is inadequate, for an animal may lose weight and at the same time make skeletal growth.

The following table represents the result of keeping 15 beef animals at constant weight for one year.

No. animal	Weight variation Pounds	Increase in ht. at withers (cm)	Increase in depth of chest (cm)	Decrease in width of chest (cm.)
1	740.0- 752.4	118.0-130.0	62.0-66.5	39.5-35.5
2	609.2- 595.6	109.0-119.75	56.0-60.75	35.0-30.75
3	1085.6-1071.8	124.5-133.0	67.0-71.0	47.0-42.0
4	1060.8-1060.0	120.5-127.5	69.0-69.75	50.5-45-75

In order to compare a full with a maintenance ration two fat Jerseys were placed on experiment. After 6 months the rations were reversed and after 9 months they were again reversed. These changes caused great variations in the general visible condition, while height curves ran fairly close together, the advantage being very slightly in favor of the full ration. The decrease in feed was a long time in showing its effect on skeletal growth. The length of time during which full height growth will continue on a low plane of nutrition is variable and probably depends upon the "constitutional vigor" of the individual.

Even an animal on sub-maintenance will make skeletal growth. An experiment[92] to determine the effect of super-maintenance, maintenance and sub-maintenance showed that for 6 months there was no apparent difference in skeletal increase but subsequently, while growth continued, its rate varied directly with the ration. The fat of an animal seems to serve as a storehouse for the preservation of that individual during adverse conditions. Aron[3] has shown that growth must cease when the reserve is gone and that a stunted animal will be the result.

He believes that the age of stunting is important and that it is far more deleterious to a young than to an older animal.

Morgulis[59] has concluded that "periodic starvation is more detrimental to the organism than acute starvation followed by a liberal food supply."

The ability of the ether-soluble portion of egg yolk or butter to promote growth after its entire cessation was noted by McCollum and Davis,[47] and the astonishing results with rats after long periods of stunting (in one case 370 days which is 100 days after growth has normally ceased) have led Osborne and Mendel[73] to conclude with Hatai[30] that a brief period of suppressed growth at any age is without injury and that recovery is rapid and complete. Here again, laboratory animals are unsatisfactory because of the difficulty of determining when such animals have completely recovered.

SYMMETRY.

Possibly one of the most striking things in the study of growth is the fact that variations of the ration affect the symmetry of the animal body. It was noted by Waters[92] that a ration low in protein produced an abnormally tall and narrow individual. He gives the following figures taken from data on his approximately 6-months-old animals.

Compared Increases	Full Fed	Moderately fed	Retarded development	Maintenance (no gain in weight)
Wd. Hip to Height Wither	1 :1.48	1:1.91	1 :2.31	1 : 3.11
Wd. Hip to Length fore-leg	1; .78	1:1.14	1:1.21	1 : 1.96
Wd. chest to length fore-leg	1: .96	1:2.33	1:4.10	

On animals started at 2 months and ending at 10 months the results were even more striking.

Compared Increases	Full	Retarded Development	Maintenance
Wd. hip to Height wither	1 : 1.84	1 : 2.48	1 : 3.87
Wd. hip to length fore-leg	1 : .95	1 : 1.30	1 : 2.46
Wd. chest to length fore-leg	1 : .97	1 : 3.13	1 : 8.00

Again it was found:-

Compared Increases	Super-maintenance. Av. ½ lb. da.gain	Maintenance No gain in weight	Sub-maintenance. Av. ⅛lb. daily loss
Wd. Hip to Ht. withers	1 : 2.01	1 : 2.87	1 : 5.00
Wd. Hip to length fore-leg	1 : 1.01	1.: 2.01	1 : 3.02

"When the animals were maintained on a low nutritive plane the effect upon their skeletal width development was more immediate and marked than it was upon their skeletal height development. The lower the nutritive plane the more marked the tendency", and "the height growth is more persistent than the width growth".[92] While these effects are less marked with small animals, Aron has drawn similar conclusions.

Why should this occur? Evvard[11] suggests that it may be due at least in part to the mechanical effect of the food in the body. He also considers the "reversion" theory. It is possible that animals under adverse circumstances will depart from their highly artificial condition and resemble their unimproved ancestors. ' At any rate,

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the tendency is in that direction, for the early ancestors were characterized by their deep, narrow chests, narrow hips and long legs.

PREGNANCY.

Pregnancy is commonly supposed to cause a great strain on the body of the dam. Early experimental work was performed by Edlefsen, Hensen and Minot.[93] Edlefsen found that the actual growth of pregnant guinea pigs is slower than that of males of the same age.

Ratio of mother - plus fetus to male	-1.164 : 1
Ratio of mother alone - to male	.848 : 1

Hensen drew the same conclusion from observations on 4 animals but Minot found exactly the reverse in dealing with a large number of guinea pigs. His pigs averaged:-

Pregnant animals	830.2 grams
Same animals after delivery	588.0 "
Normal unmated females	532.1 "

The breeding females after parturition were on the average 55.9 grams heavier than corresponding unmated ones.

Watson[93] found that rats which had produced three litters of young were on the average 9 percent heavier (with one exception) than the unmated rats of the same age and kept under the same conditions.

From his observations on swine Griswold[21] concludes that "weights show no particular difference in the growth of the open and pregnant groups. Measurements seem to favor a greater growth of the open group but this is not decided and may all be due to individuality." "Pregnant gilts make about as much growth as open gilts receiving the same feed. Perhaps with gilts running together pregnancy promotes growth."

According to Minot[58a] "Gestation does not represent a tax upon the parent but a stimulus - it does not impair growth but on the contrary favors it."

Musser[60] finds that the fetus is produced without any appreciable addition of food. Foeti were produced on maintenance rations and the cows remained at constant weight.

From records of experimental animals at the University of Missouri, Professor Eckles[9] has concluded that "gestation does not check the growth of a heifer to any appreciable extent".

The fact that similar results have been obtained with different species leads to the general belief that the growth of an animal is not materially influenced by pregnancy.

LACTATION.

Pregnancy and lactation are closely related, yet while pregnancy can be said to have practically no effect upon growth, lactation will be admitted by all to have a very decisive effect. Females grow thin during lactation and, under poor nutrition, milk is produced even at the expense of the tissues of the body.

Even Watson[93], who showed a gain in weight of rats during pregnancy, admits that there is a rapid loss with both rats and guinea pigs during lactation. Minot[56] agrees with Watson on the effect of lactation.

Regan[82] concludes that lactation has a strong tendency to check growth and that "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".

Griswold[21] found that "lactation greatly retarded growth and in case of one animal seems to have stopped it entirely, except possibly in the skeleton".

From the foregoing references and from the results of work with dairy heifers at the University of Missouri it may be concluded that, while gestation does not materially check growth 'the production of milk exerts a very pronounced effect. Lactation is evidently a much greater tax upon the animal than gestation".[9]

NUTRITION.

Food is essential for the continuation of life and growth. The earliest belief was that the amount of food determined the amount of growth. From this early idea of food requirement came a division of food into its constituents, and proteins, carbohydrates and fats were considered separately. Energy came to be a basis of measurement and the importance of mineral matter began to be considered. After this came the division of proteins into amino-acids and the use of the so-called "purified foods", and now investigators are working with those substances - vitamines or accessories or whatever they may be called - that seem to be the elements in nutrition which are absolutely essential for growth.

For years the question of measuring energy requirements was debatable. Rubner[52] emphasized the importance of the body-surface as a determiner and he had many followers. Recently Murlin and Hoobler[52] announced that it could be more accurately measured by weight and that the product of weight and specific gravity was still more nearly correct. The question is still under consideration.

It was maintained by Voit[52] that growing animals consumed a large amount of protein and destroyed extremely little. Rubner believed that this early destruction of protein is for repair, and states - "This behavior of protein during growth is a physiological necessity; the relative importance of the physiological functions involved determines the order in which they are filled. First, losses are replaced; next growth ensues; thirdly, the usual metabolism of protein for the production of heat occurs." He has assumed that food must be in excess before growth can take place.

The law which Lusk[37a] formulated is that in the normal development of young of the same age and species, a definite percentage of the energy content of the food is required for growth irrespective of the size of the individual.

Hawk[31] says that proteins are absolutely necessary to the uses of the animal organism for the continuance of life, and they cannot be satisfactorily replaced in the diet of such an organism by any other dietary constituent.

From the early idea that the foods were used directly in building up the body, it gradually became the belief that the food-products do not enter the "cycle of metabolism" unaltered, but as decomposition products or as the "B a u s t e i n e" or nutrient units.

PROTEIN METABOLISM.

Protein digestion consists of a breaking down, by means of cleavage and hydration, into proteoses, peptones, polypeptids and amino-acids. These amino-acids are the fundamental "building stones" and are supposedly absorbed, unchanged, by the blood and carried to the tissues of the body where they may be resynthesized to form the proteins required by the animal.

The early conception was that a "protein was a protein" but at present proteins are differentiated on the basis of their amino-acid content. Much has been said of "protein minimum". Cathcart[75] defines protein minimum as the quantity of protein which must be ingested in order to prevent loss of protein from the body." It cannot be said that a given number of grams of protein will constitute the protein minimum because of the variability of proteins in the amino-acid content, and it is becoming more and more necessary to define the "protein minimum" in terms of the essential amino- acids contained.

In studying the protein requirements for growth it has been said by Mendel that "prolonged growth is an admirable index of protein synthesis and of the adequacy of the dietary."

As a result of a careful study of the proteins from different sources by means of feeding experiments with these isolated proteins, it became recognized that some are adequate while others are inadequate for growth. To carry on an experiment of this nature necessitates an absolutely controlled diet in which the protein factor alone is the variable. The method of this control was not easily solved, but Osborne and Mendel[52] overcame the difficulty by using protein-free-milk as a basis for carbohydrate and inorganic matter in the artificial diet. Milk has long been known as an adequate food for growth. The removal of the protein and fat then, gives a basis upon which proteins can be compared. Many proteins were used and in some cases growth was not obtained, while with other diets consisting of protein-free-milk, sugar, starch and certain of the proteins, growth seemed to be normal even to the production of young to the third and fourth generations. How this could take place was not understood, but it was concluded that a synthesis of some substances by the animal body must have taken place.

Not only have purified foods been used, but numerous experiments have been carried on with the different cereal grains. At the Wisconsin Agricultural Experiment Station[24] it was found that when their rations were restricted to the wheat plant, bovines were unable to perform normally and vigorously the physiological functions of reproduction and the secretion of milk. While rations of the corn and oat plant permitted the performance of these functions in a satisfactory manner, the results were less satisfactory with the oat-plant ration. Rations from all three sources seemed equally efficient for growth in this experiment. Changes in diet produced rapid changes in physiological functions. Hart and McCollum[23] found that corn meal and gluten feed did not produce growth without the addition of mineral and that the wheat kernel alone was also inadequate, while Waters[90] did not get growth with swine on cornmeal, with corn meal and ash or with corn meal and protein-free-milk where there was a decline from 50 to 27 pounds in 6 months.

The result of feeding experiments has been to classify the proteins which have been studied as follows;-

Adequate for growth:

1. Casein (milk)
2. Lactalbumin (milk)

3. Ovalbumin (Egg)
4. Ovovitellin (egg)
5. Edestin (Hempseed)
6 Globulin (Squash seed)
7. Excelsin (Brazil nut)
8. Glutelin (maize)
9. Globulin (cottonseed)
10. Glutenin (wheat)
11. Glycinin (soy bean)
12. Cannabin (Hempseed)

Inadequate for growth:-

1 Legumelin (soy bean)
2. Vignin (vetch)
3. Gliadin (wheat or rye)
4. Legumin (pea)
5. Legumin (vetch)
6. Hordein (Barley)
7. Conglutin (yellow (Blue or lupin)
8. Gelatin (Horn)
9. Zein (maize)
10. Phaseolin (white kidney bean)

A consideration of their chemical analyses shows that the inadequate ones are almost universally deficient in certain amino-acids. It is interesting to note that lactalbumin, casein and vitellin which are usually associated with growth are relatively high in lysine-content. The effect upon the organisms of these different proteins and a consideration of their chemical analyses led to the belief that maintenance is impossible on a protein which lacks the indol-nucleus or cyclic group which is characteristic of tryptophane and tyrosine. It seems that growth is impossible on a protein devoid of lysine and that a body can maintain itself on a protein upon which it cannot grow.

In order to confirm these ideas, Osborne and Mendel and McCollum and Davis, together with their co-workers have carried on an elaborate series of experiments with albino rats. Knowing that gliadin is practically devoid of lysine* and that it produced maintenance but not growth, lysine was added to the gliadin ration and was followed by a rapid growth. It is interesting to note at this point, the striking effect of high and low lysine feed with poultry at the Kentucky Agricultural Experiment Station[6] where the lysine content of the food seemed to be the determining factor in the growth and development of the chicks.

To further establish the proof Osborne and Mendel began the feeding of zein of corn**. Zein is devoid of both lysine and tryptophane and, as they anticipated, the feeding of this substance not only prevented growth but caused a decline in the weight of both growing animals and adults. The addition

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*It has been recently proven that gliadin contains a minute quantity of lysine.

**The protein of corn contains 58 percent zein.

of trypotophane caused the weight to be maintained for a long period and the supplementing of lysine caused the rapid resumption of growth.

The failure of any function to operate does not necessarily show the entire absence of its causative amino-acid; but shows that, if present, it is in limited amounts.

The results obtained by using different combinations of rations have only substantiated the theory which promoted their use. Apparently tryptophane and lysine cannot be synthesized in the animal body but must be supplied in the ration; and Osborne and Mendel write, "No amount of energy or protein, however abundant, has induced growth in our animals in the absence of lysine". We are beyond the days of assuming that a "protein is a protein", and must measure protein requirmements by the content in the ration, of the essential amino-acids which cannot be synthesized in the animal body. This knowledge is of great practical value because it permits the balancing of a ration - not only in respect to the proteins, carbohydrates and fats but according to amino-acids. A complete ration may thus be made by mixing two or more incomplete substances together or to quote Mendel[52], "the amino-acid short-comings of one protein can be made good by supplementing it with another protein in which they do exist." By this method a great saving in protein substance will be realized. The importance of a knowledge of the chemical analyses of feeding stuffs is emphasized, and the lack of knowledge on the whole subject regretted.

CARBOHYDRATES.

Carbohydrate food is absolutely essential for animals of all ages. Other than in regard to their digestibility the different carbohydrates have seemed to be of nearly equal value. Carbohydrates are stored in the liver and in the muscle tissue as glycogen. From these storage places they may be drawn as D-glucose, as they may be needed to keep up the glucose content of the blood, or to be burned in the tissues for the production of energy. The value and nature of carbohydrates have been longer known than the value and nature of proteins and will not be discussed further.

MINERAL MATTER.

Growth cannot continue for long periods without mineral matter. Much experimental work has been performed to determine its importance and McCollum and Davis[43] conclude that "the addition of salts alone to a ration derived entirely from wheat or wheat and wheat-gluten gives a diet which is a wonderful improvement over the grain alone, yet such rations give less than half normal growth and do not suffice for prolonged maintenance." In one of their experiments the addition of an excess of salt checked growth and in another prevented reproduction. Waters[90] found no advantage in adding ash to a corn ration for swine, while Woodward[97] could not draw conclusions from his studies except that in a general way all functions are dependent upon the mineral matter in the ration. It is safe to say that knowledge is decidedly limited concerning the mineral requirements for growth.

NEWER THEORIES.

While the amino-acid theory explained many things, investigators have continued and have considered the importance of many substances such as nitrogen, phosphorous, lecithin, cholesterol, glycerides, phosphatids and lipoids, but with little satisfaction.

For a long time fats and oils have been considered necessary for growth, but until recently the method of obtaining fat-free foods has not been known. Satisfactory results have consequently been practically impossible in the early work. Osborne and Mendel at one time believed they had proven fats to be dispensable in the diet. They later discovered, as did other investigators, that all the work with purified foods had been rather unsatisfactory in that experiments had been conducted for only insufficient periods of time. The fact became recognized that sooner or later animals on purified foods ceased to grow or thrive and begin to show symptoms of disease. The observed condition was explained by assuming that toxic substances were present in the foods which were harmless to a properly nourished animal, but which were injurious to one weakened by inadequate nutrition.

Osborne and Mendel[62] showed that when a part of the lard in a protein-free diet was replaced by unsalted butter or egg-yolk, growth was quickly resumed. They at once concluded that fats could not be dispensable. This resumption of growth caused much speculation. Evidently some unknown substance is responsible for the growth phenomena. Believing that such a substance exists Funk[62] has represented it by the word "vitamine" and the "vitamine" theory has been popularly received.

In December 1915 Funk and Macallum[17] published the conclusion that butter or purified butterfat is not suitable for maintenance or growth, even in large quantities, but that 2 to 6 percent of dried brewer's yeast answers all requirements when supplementing the butter as the fat-portion of the diet. This seemed like a direct contradiction to previous conclusions concerning fats and oils, but on turning back to a November, 1915 publication by McCollum and Davis[48], the explanation is found. These writers consider two distinct classes of vitamines or accessories - one soluble in water and alcohol but apparently not in fats, and found in lactose, egg, wheat embryo, etc., and the other soluble in fats. Both must be present before growth can take place and the rate of growth is dependent upon the amount of the accessories present.

The explanation[48] of the early successes with a fat-free basis by all investigators lies in the fact that their rations usually contained either lactose or casein or both, and that these substances contain the water-soluble accessory unless absolutely pure. Thus in the early successful experiments, the water-soluble accessory was furnished by the invariable dietary while the fat-soluble accessory was carried by the fats which were used. With this conception it can be concluded that fats are essential, but that pure or nitrogen-free fats in themselves are inadequate for growth.

It has been found that the fat-soluble accessory of butterfat is not injured by saponification, or by live steam for two-and-one-half hours, that the water-soluble accessory is uninjured by steam under 15 pounds pressure for one hour, and that it is the liquid portion of butterfat or the "butter-oil", which contains the essential product.

This theory explains some things which were not satisfactorily answered by the amino-acid theory, but the nutrition of growth is a subject which is continually becoming more and more complicated and, like all other scientific problems, is undergoing a rapid evolution.

THE PROBLEM

It is unquestionably desirable to know more about the growth of domestic animals, and this problem has been undertaken for the purpose of studying the growth of dairy heifers. The study consists of a consideration of normal growth, or of the growth of animals under supposedly normal conditions, and the growth of experimental animals under a variety of different conditions.

An attempt will be made to represent growth by different methods and to compare, by one or more of these methods, the relative growth of some of the individual body parts. This preliminary work will be followed by a representation of the effect of specific factors upon the general growth and mature size of the animals under consideration.

This consideration has been based entirely upon animals of the Holstein and Jersey breeds, both because of the incomplete data on Ayrshires and Guernseys, and because of the belief that the growth of the different dairy breeds follows the same general law.

SOURCE OF DATA.

The data upon which this study is based have all been taken upon animals in the dairy herd of the University of Missouri. Birth weights have been taken of practically all calves in the herd, as have the weights of their dams at parturition, and monthly weights and measurements have been taken on animals under normal conditions for the purpose of establishing a normal growth-value. The greater part of the consideration, however, is based upon the experiment which was begun in 1906* for the purpose of determining:

1. The effect of liberal as compared with light rations during the growing period, and
2. The influence of the age at first calving upon the development of the animals.

Group I was heavy-fed and was sub-divided into early and late-calving groups.

Group II was heavy-fed and was subdivided in the same way as group I.

The heavy-fed animals received the maximum

*The outline of this experiment is found in Bul. 135 of the Missouri Ag. Exp. Sta. 1915.

ration that would be consumed up to the time of first calving. Up to the age of six months they received whole milk, grain and alfalfa hay, at which time they were weaned and placed on a heavy ration of hay and grain. A part of the group were on pasture during the summer in addition to the regular ration.

The light-fed animals received whole milk for about two weeks and were then gradually changed to skimmilk. Alfalfa hay was fed as soon as it would be taken, but no grain was given. At the age of six months the heifers were weaned and given nothing but alfalfa hay, or alfalfa hay and pasture till the time of first calving.

While the experiment was planned primarily to consist of a heavy and a light ration, it was later decided that it was a comparison between a medium and a very liberal one.

The Jerseys were bred so that first calving occurred, on an average, at 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, consisting of an abundance of silage, hay* and grain.

*Alfalfa, clover and cowpea.

MEASUREMENTS.

The height at withers and the weight of the normal animals were taken every month up to the time of the first calving. The animals on the above experiment were weighed at as nearly as possible the middle of each month. At the same time twenty-one measurements were taken on each animal. All skeletal measurements were taken in centimeters, and weights were taken in pounds. The values will be expressed in these units of measure in the following tables unless otherwise specified.

A few of the animals were started on the experiment before this system of measuring was established. With these exceptions weights and measurements were taken monthly from birth, until the rate of growth was greatly reduced. Following this the measurements were taken at periods varying from three to twelve months, until no increase was apparent. In the case of a few animals, figures are available up to the 96th month. As a rule, the skeletal growth was practically complete at five years of age. The weights continued to increase for some time after the skeletal growth had ceased, and it is very difficult to determine when an animal has reached maturity of body-weight.

A PRELIMINARY STUDY OF THE AVAILABLE DATA

In considering a problem of this nature, one of the first questions which presents itself is in regard to the method of measuring growth. It is all the time becoming more fully understood that weight alone is inadequate and that skeletal measurement is essential in the proper measurement of growth. If skeletal measurement is essential, which of the measurements shall be used? Can any one measurement be used as a satisfactory index of the growth of an animal? In many investigations the height at withers has been used. Is it satisfactory to base conclusions on one measurement?

In order to determine whether one measurement is as good as another or whether one measurement can be used as an index of growth, it has seemed advisable to select a part of the large number of available measurements in such a way that the different parts of the body will be fairly well represented, and to study from these the relative growth of these different body-parts.

In such a consideration the height of the body is very important and the height at withers and height at hip-points, were selected. The heart girth was selected as representative of the chest development, while the width at hip-points was used to represent the width of the posterior part of the body. One more measurement seemed necessary to represent the length of the body, and the length from the point of the shoulder to the point of the ischium was selected.

Having selected these five measurements which seem to represent, in a general way, the dimensions of the animal, the next problem was to select the animals to be used in the consideration. Only a part of the available animals have complete measurements from birth, and it seemed fair to select, and to base the preliminary study upon sixteen animals, four of which were included in each of the four following groups:

1. Heavy-fed Jerseys
2. Heavy-fed Holsteins
3. Light-fed Jerseys
4. Light-fed Holsteins.

In a preliminary study of this nature it is not necessary to determine the values for each month, and in order to simplify matters the values have been calculated only for the ages of 1, 2, 3, 6, 9, 12, 18, 24, 30, 36, 48 and 60 months. The relatively rapid growth at an early age was the reason for the short periods at the beginning, and the gradual lengthening of the intervals as the age of the animal increased.

The measurements and weights were taken at as nearly as possible the middle of each month. The calves, of course, were dropped at different times within the month. The result was that in the majority of cases, the calves were not at any even number of months of age when the measurements were taken. In order to allow for this condition it became essential to correct the values in such a way as to eliminate the greater part of this error. If, at the time of the measurement, the calf was more than five days over or under the exact month in age, corrections were made up to the age of six months. From the age of six to twelve months similar corrections were made for a variation of ten or more days. After one year of age, no correction was made, because by that time the rapidity of growth was somewhat diminished. Wherever possible the correction was made on the basis of the rate of daily gain in centimeters during the preceding period. That is, if the animal was five months and seven days of age at the time of measurement, and had gained six centimeters in height during the preceding thirty days, 1.4 centimeters would be subtracted from the measurement as taken, to give the value for exactly five months.

In a few cases measurements were not taken according to the plan of the experiment and vacancies occurred. These were filled by dividing the difference between the two nearest values by the time in months between the measurements. If the value for the 10th month was 110 centimeters and the value for the 12th month was 112 centimeters, the value to be inserted for the 11th month would be 111 centimeters.

At the beginning of the experiment some of the calves were several months of age, consequently no values were available for them until the fifth or sixth month. Not many of these animals were selected, but in one or two cases it became necessary to supply the missing figures. This was done by working backward from the earliest available value, on the basis of the average percentage increase of the other members of the group. Thus if the average height at withers of the group, for the sixth month happens to be 100 centimeters, and for the fifth month 80 centimeters, the value for the sixth month is 125 percent of the value for the fifth. Now if the value for the sixth month of the animal with incomplete measurements is 110 centimeters, the division of this value by 125 percent gives 88 as the new value for the fifth month.

Let a represent the average value for the group for the sixth month,

b the value for the animal with incomplete measurements for the sixth month,

c the average value for the group for the fifth month, and

x the individual value for the fifth month which is to be determined.

Then $\frac{a}{c} = y$ and

$$\frac{b}{y} = x.$$

The same method was repeated on the basis of the fourth and fifth months and so on, until the value for the first month was determined.

In cases where the values were incomplete for the sixtieth month, the nearest value, or the average of several values was used.

At first it was though advisable to consider the difference between the first and last values as 100 percent and to distribute the gain for each period proportionally. By this method the total increase in each case had to be 100 percent, therefore, the curves all started and ended at the same, or at equally distant points. Although there were slight differences in the curves, they did not show the differences in value to good advantage, and the system was unsatisfactory and was abandoned.

The second method of plotting to be considered was to represent the amount of the increase at each point by the percentage increase at that point over the first measurement. By this method, if the first measurement of one animal, or the average of a group is 70 centimeters and the next is 84 centimeters, the increase is 20 percent. If the next or third measurement happens to be 91 centimeters, the amount of the increase at this point is 30 percent. In each case the gain is calculated on the increase over the first measurement. This method does not show the rate, but the amount of growth in percent.

The _third_ method to be considered was to show the _rate_ of increase by calculating the increase during each period as a percentage increase over the preceding measurement. By this method each increase is taken as a unit and is dependent upon the two immediate values only. The rate is wholly dependent upon the size of the animal at the time of the consideration and must necessarily diminish rapidly, because the larger the animal, the smaller will be the percentage value which one centimeter increment will give. These two methods at first seem contradictory because when expressed graphically they give reversed curves, but a more careful consideration shows them to be consistent.

A _fourth_ method of representing growth is by plotting the increases, by periods or by months, directly in centimeters or other units of measurement. This is very satisfactory in comparing the relative increases of corresponding measurements of animals under different conditions, but it cannot be used in comparing the relative increases of the different parts of the body, for in this case the attempt might be to compare the small value showing the increase in centimeters of the width at the hip-points with the value which represents the increase of the heart-girth or the length of the animal. The only way of comparing the ralative growth of the body-parts is by the use of some percentage basis.

A fifth method is, like the fourth, unsatisfactory in showing the relative growth of parts. This method is a very simple one and consists of plotting the values of the measurements as taken. The plot shows directly the size of the animal at any age.

The consideration of the second method shows some interesting facts. Using the values for the age of one month as a basis, it is worthy of note that from this point to maturity, which for this purpose is taken as at sixty months, the amounts of the increase of the body-parts in percent are:-

Height at withers	73.9 %
Height at hip-points	66.3 %
Shoulder to ischium	117.3 %
Heart girth	126.9 %
Width at hip-points	207.2 %

These values may be seen in Table 6 and Plate 1.

From these values it at first seems that one measurement cannot be taken as representative of the general body-growth. Surely, when an animal does not double its height at withers or at hip-points, when it more than doubles its heart-girth and length and more than triples its width at hip-points, the growth of the parts of the body is all out of proportion.

In order to still further study this condition, a set of comparisons have been calculated to determine whether or not the increases are in the same ratio at the diffferent ages as they are at maturity. If such is the case, while the body does not grow symmetrically, one measurement can as well represent the total growth as any other or of all. These ratios were derived by dividing the percentage increases of the height at withers at different ages by the percentage increases of the other measurements for the corresponding ages. The ratios, then, were derived from the figures in Table 6, and the results of the calculations may be found in Table 7 and Plate III. It will be noted that the ratios are fairly constant through the life of the animal, the greatest variations occurring in the comparison of the values for the heart-girth and width at hip-points with the values for the height at withers, which is used as the basis for the comparison. The decrease in the value, as maturity is reached, obtained from the division of the height at withers by heart-girth increases, is explained by the observed fact that in more mature life a great deal of flesh-deposition takes place. This makes an excessive increase in the value of the heart-girth measurement, and consequently decreases the value derived from the division of the percentage of increase of height at withers by heart-girth.

It is a common observation that the hips broaden rather rapidly at certain periods and that this broadening continues in the more mature animal after other parts of the skeleton have almost ceased to grow. This condition will have exactly the same effect upon the value of the ratio as has already been explained in connection with the heart-girth. A consideration of the causes for the excessive development of the width at the hip-points will be considered later.

Plate I which represents the amount of the increases of the different parts is plotted by the second method described. Plate II, which represents the rate of growth, is plotted by the third method. It may be explained in this connection that wherever, in any of the following plates, the average increase per month is plotted for a period, the average value derived is placed at the end of the priod. This means that if the average monthly gain from the ninth to the twelfth month is 4 percent, the value of 4 percent will be placed at the point on the scale which represents twelve months. This applies to Plate II, and to others which will be considered, but does not apply to Plate I. The Plates I and II at first seem contradictory because in Plate II the greatest increase in width at the hip-points seems to occur at the beginning, while in Plate I it appears to occur at the end. A more careful consideration shows them to be consistent. Plate I shows the AMOUNT, while Plate II represents the RATE. In both it is clearly shown that the increase in the width of hip-points continues in general till a later age than the other measurements, and consequently that this value makes a greater gain. The other measurements are equally consistent in the two methods of plotting.

The constancy of the relation of increases to the height at withers, of the height at hip-points, length of body, and heart-girth shown in Table 7 have led, on the whole, to the assumption that any of the fundamental measurements may be used with a fair degree of accuracy, as an index of growth, and in this study the height at withers has been adopted.

TABLE 1

HEIGHT AT WITHERS

Age in Months	Average measurement in Cm.	Amount increase over first measurement in percent	Rate increase per month over preceding meas percent	Actual increase per months in Cm.
1	73.7			
2	78.0	5.8	5.8	4.3
3	82.4	11.8	5.6	4.4
6	96.6	31.0	5.66	4.7
9	103.2	40.0	2.26	2.2
12	109.3	48.3	1.96	2.0
18	116.9	58.6	1.15	1.26
24	122.5	66.2	.80	.93
30	124.5	68.9	.26	.33
36	125.8	70.7	.17	.21
48	127.4	72.8	.10	.13
60	128.2	73.9	.05	.07

TABLE 2

HEIGHT AT HIPS.

1	76.6			
2	80.5	5.0	5.0	3.9
3	85.7	11.8	6.4	5.2
6	99.9	30.4	5.5	4.7
9	106.2	38.6	2.1	2.1
12	110.7	44.5	1.4	1.5
18	119.8	56.4	1.36	1.51
24	123.0	60.5	.45	.53
30	125.9	64.3	.4	.48
36	127.3	66.1	.2	.23
48	127.6	66.5	.01	.03
60	127.4	66.3	- .008	- .017

TABLE 3.

POINT OF SHOULDER TO ISCHIUM.

Age in Months	Average measurement in Cm.	Amount increase over first measurement in percent	Rate increase per month over preceding meas. in percent	Actual increase per months in Cm.
1	73.3			
2	79.8	8.8	8.8	6.5
3	87.9	20.0	11.4	8.1
6	107.3	46.4	7.3	6.46
9	118.7	61.9	3.53	3.80
12	125.2	70.8	1.8	2.16
18	139.4	90.1	1.9	2.36
24	148.6	102.7	1.1	1.53
30	152.5	108.0	.43	.65
36	155.8	112.5	.36	.55
48	157.9	115.4	.1	.17
60	159.3	117.3	.07	.11

TABLE 4.

HEART GIRTH

1	78.2			
2	85.7	9.6	9.6	7.5
3	93.9	20.1	9.6	8.2
6	116.4	48.8	7.96	7.5
9	125.9	61.0	2.7	3.16
12	136.8	74.9	2.86	3.63
18	152.6	95.1	1.91	2.63
24	160.2	104.9	.83	1.26
30	167.1	113.7	.71	1.15
36	168.7	115.7	.15	.26
48	175.2	124.0	.31	.54
60	177.5	126.9	.10	.19

TABLE 5.

WIDTH OF HIPS

Age in months	Average measure in Cm.	Amount increase over first measure in percent	Rate increase per month over preceding meas in percent	Actual increase per month in Cm.
1	16.8			
2	18.9	12.5	12.5	2.1
3	21.5	28.0	13.7	2.6
6	28.5	69.6	10.8	2.32
9	32.4	92.9	4.56	1.30
12	36.0	114.3	3.7	1.20
18	41.9	149.4	2.73	.98
24	44.8	166.6	1.14	.48
30	47.8	184.5	1.11	.50
36	48.5	188.7	.23	.12
48	50.6	201.2	.36	.17
60	51.6	207.2	.16	.08

TABLE 6.

RELATIVE AMOUNTS OF PERCENTAGE INCREASE OVER FIRST MEASUREMENT OF THE DIFFERENT BODY-PARTS.

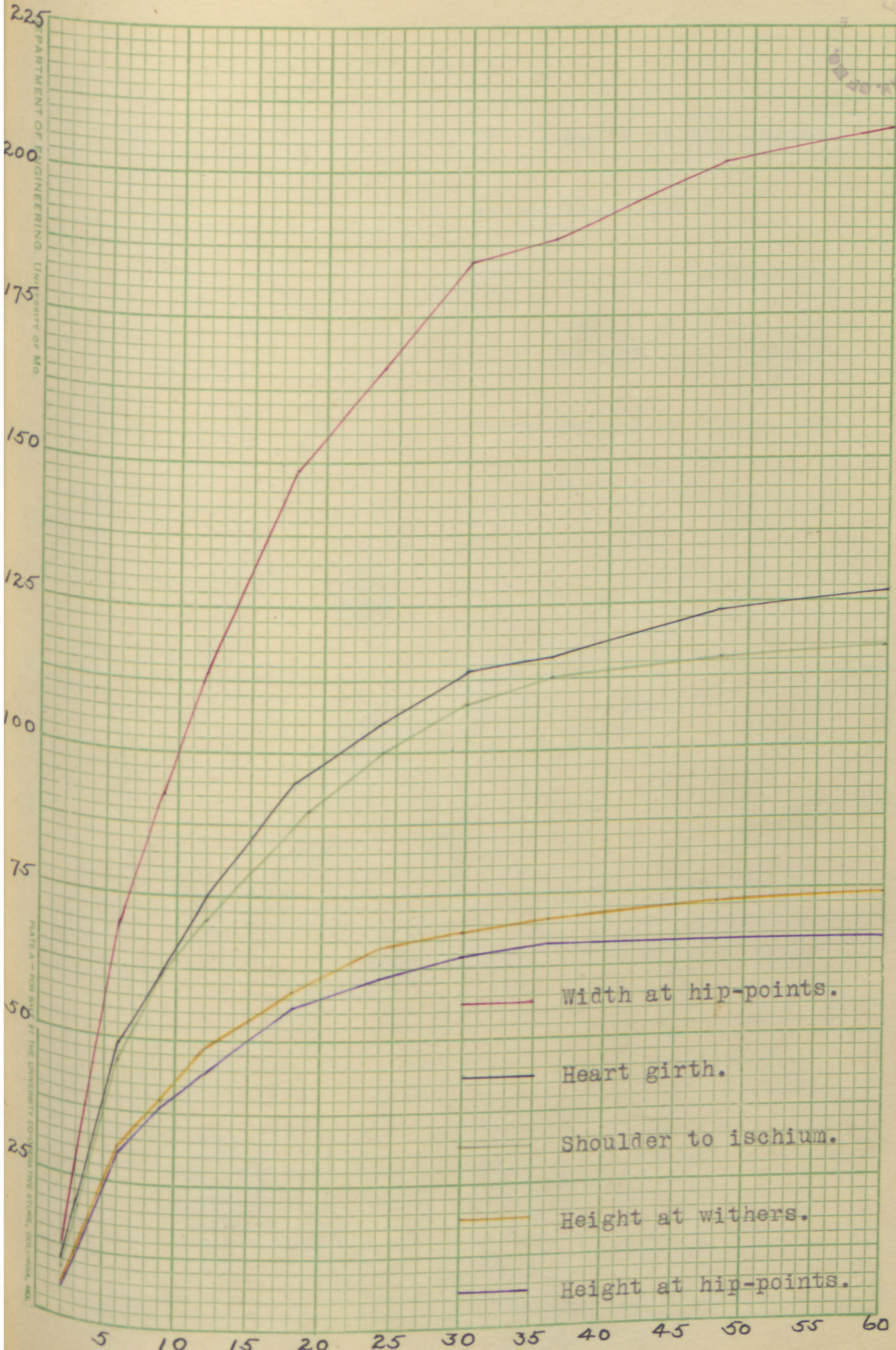
Age in months	Height at withers	Height at hips	Shoulder to Ischium	Heart Girth	Width of hips
1					
2	5.8	5.0	8.8	9.6	12.5
3	11.8	11.8	20.0	20.1	28.0
6	31.0	30.4	46.4	48.8	69.6
9	40.0	38.6	61.9	61.0	92.9
12	48.3	44.5	70.8	74.9	114.3
18	58.6	56.4	90.1	95.1	149.4
24	66.1	60.5	102.7	104.9	166.6
30	68.9	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

TABLE 7

A COMPARISON, AT DIFFERENT AGES, OF THE AMOUNT OF PERCENTAGE INCREASE OVER THE FIRST MEASUREMENT.

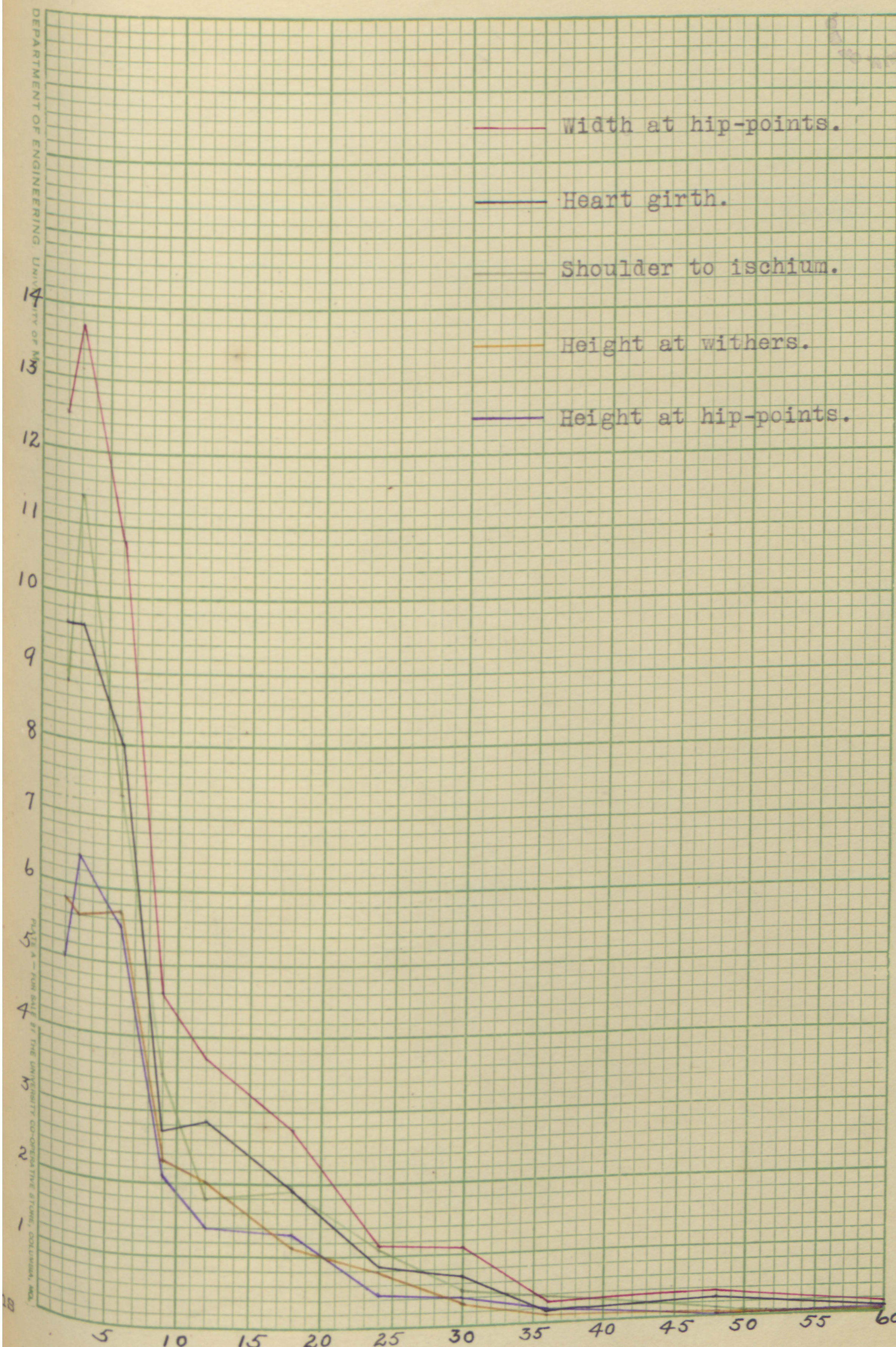
Age in Months	Height Withers / Height Hips	Height Withers / Shoulder to Ischium	Height Withers / Heart Girth	Height Withers / Width Hips
	A	B	C	D
2	1.160	.659	.604	.464
3	1.000	.560	.587	.421
6	1.019	.668	.635	.445
9	1.036	.646	.655	.430
12	1.085	.682	.644	.422
18	1.039	.650	.616	.392
24	1.092	.643	.630	.396
30	1.071	.638	.606	.373
36	1.069	.628	.611	.374
48	1.094	.631	.587	.361
60	1.114	.630	.582	.356
Av.	1.071	.639	.614	.403

Plate I.



The increments of the different body-parts expressed as the percent of increase at each point over the first measurement.

Plate II.



The rate of increase of the different body-parts, expressed as the percent of increase of each period over the preceding measurement.

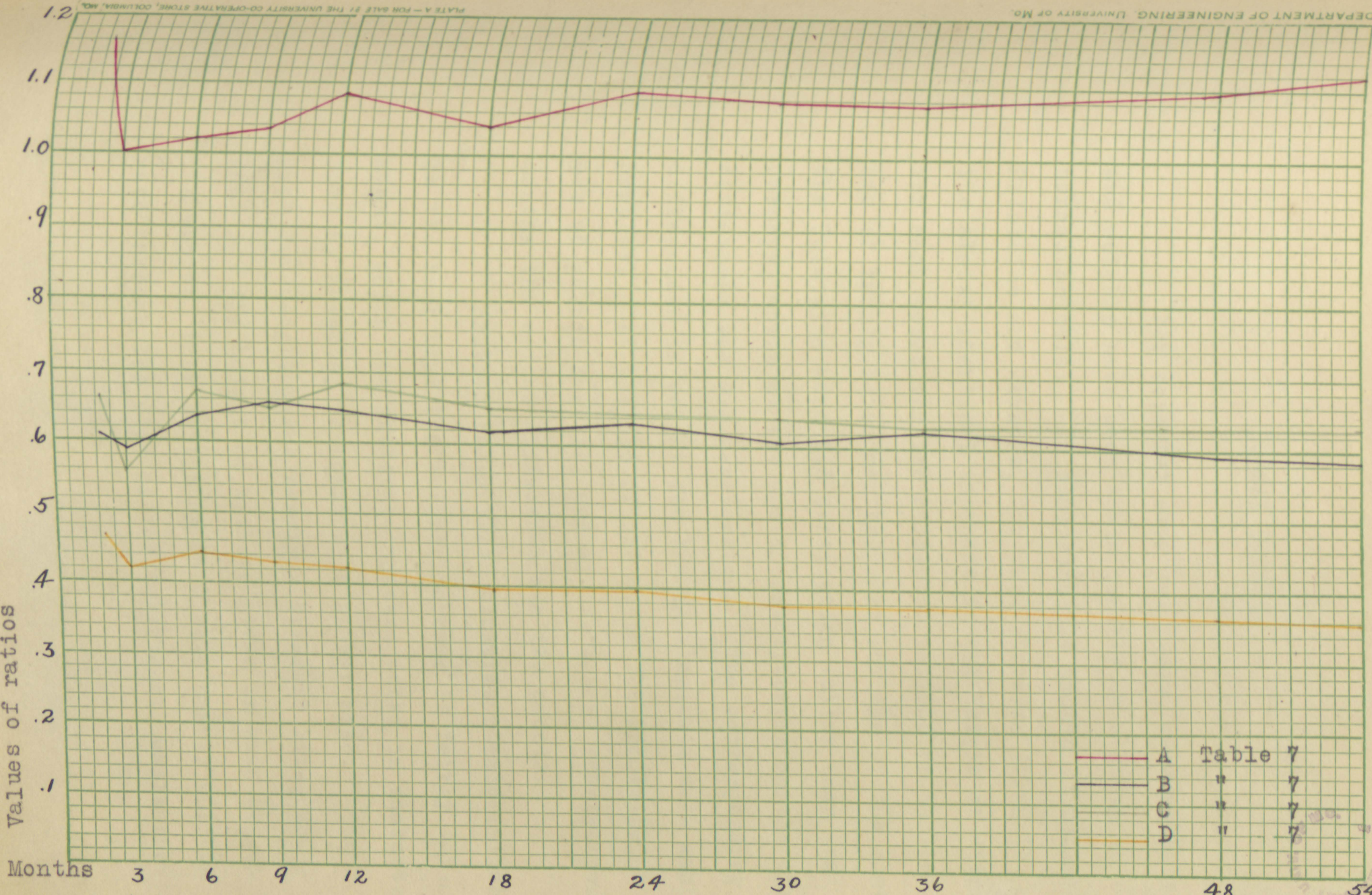


Plate III.

A comparison, at different ages, of the amount of percentage increase over the first measurement. Expressed in the values derived by dividing the percentage increment of height at withers by the corresponding values for the other body-parts.

NORMAL GROWTH.

For somewhat over two years, measurements and weights have been taken monthly on a group of normal animals. In comparing the growth of normal Holsteins and Jerseys, the most striking thing is the almost identical increase in the height at withers for each breed for the different periods up to the age of twenty-seven months. At the age of one month the Holsteins were 6.5 centimeters taller than the Jerseys, while at the age of twenty-seven months the difference was 6.4 centimeters. The corresponding differences in weight for the same animals were much greater. At the age of one month the Holsteins were 45 pounds heavier, and at the age of twenty-seven months the weight difference was 170 pounds.

Another thing which deserves consideration is the fact that the weight-increase is fairly constant, while the skeletal-increase curve is characterized by a rapid, followed by a slower rise. The plot for weight gives nearly a straight line, while that for the height at withers gives an even curve. The weight, then, continues at a more nearly uniform rate through the life of the individual, while the height-growth is more rapid at the beginning and ceases at an earlier age. By this statement it is not intended to imply that great variations do not occur in weight, but that the weight-increases are distributed over a much longer period of time. An example of the great fluctuations in weight-increases may be seen in Plates VI, XIII and XIV.

It is particularly interesting and gratifying to note that the normal values which were calculated by Burlingham and Gillette in 1914 and which were based upon data much less complete than at present, compare almost identically with those obtained from the animals in the so-called normal groups. These comparisons are made from one to twenty-four months and may be found in Table 8. The uniformity of growth already referred to is represented in Plates IV and V. Plate VI shows the average monthly gain in pounds of the normal Holsteins and Jerseys up to the age of thirty months. The cause of the decided drop in this plot at the points representing the periods of twelve to fifteen months for Holsteins and fifteen to eighteen months for Jerseys is not understood. The drop in the Holstein curve may be partly due to the fact that for a number

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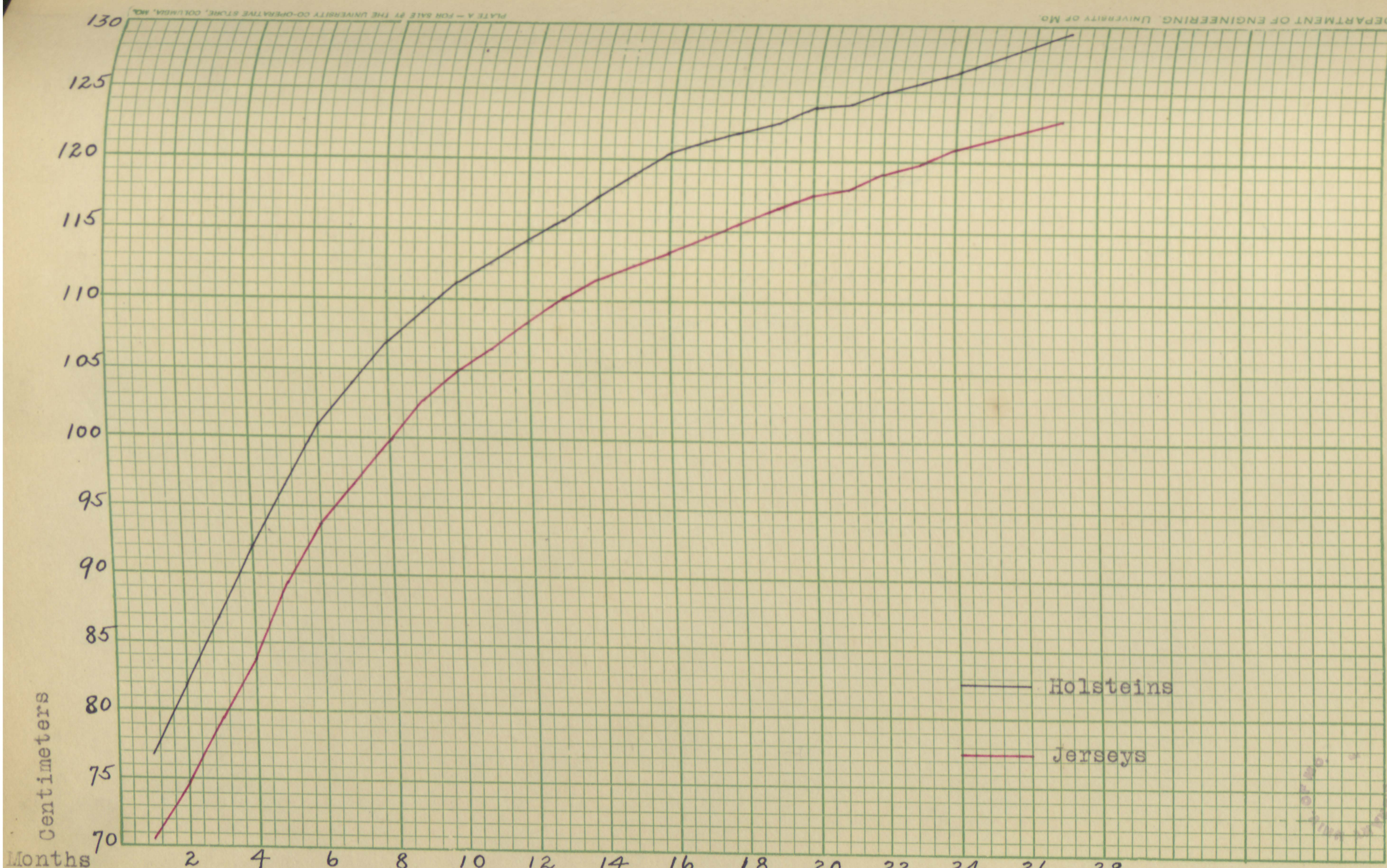
of the individuals, this period represents winter months. The fact that two Jerseys which were smaller than the average were introduced at the seventeenth and eighteenth months may account for a very small part of the drop for this period in the Jersey group.

TABLE 8

COMPARISON OF NORMALS WITH PREVIOUS NORMALS.

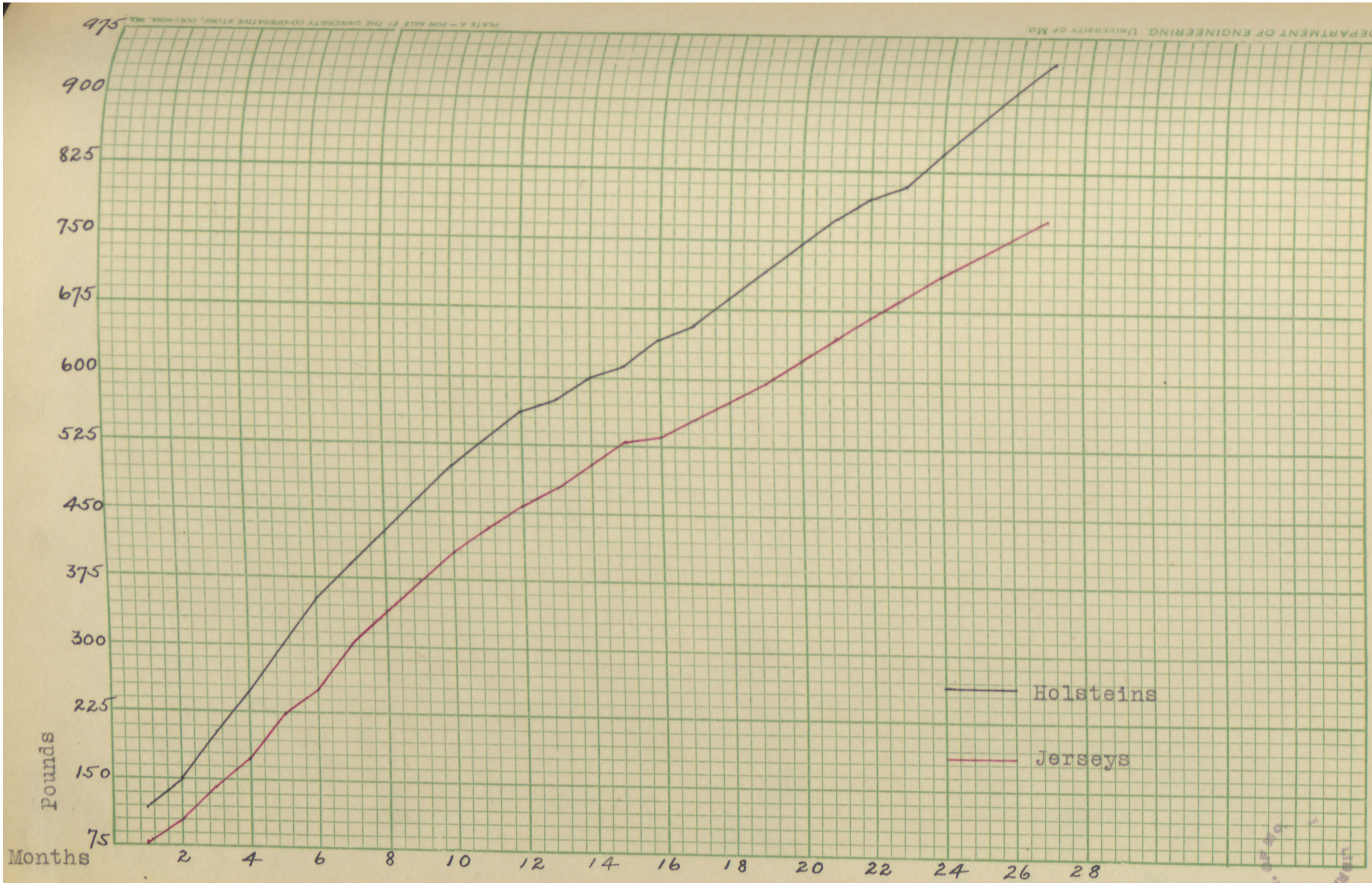
Age in Months	Holsteins: New Values: Withers	Holsteins: New Values: Weight	Holsteins: Burlingham and Gillette: Withers	Holsteins: Burlingham and Gillette: Weight	Jerseys: New Values: Withers	Jerseys: New Values: Weight	Jerseys: Burlingham and Gillette: Withers	Jerseys: Burlingham and Gillette: Weight
1	76.8	121	76.5	123	70.3	76	70.0	80
2	82.0	157	82.4	155	74.7	105	75.2	116
3	86.8	200	87.3	203	79.3	140	80.6	156
4	92.0	249	92.3	250	83.9	174	86.2	195
5	96.5	302	97.3	298	89.3	222	90.3	235
6	100.9	349	102.0	350	93.7	260	94.5	265
7	104.0	389	104.8	380	96.8	302	97.8	297
8	107.1	425	106.6	416	99.8	340	101.0	334
9	109.1	466	108.6	444	102.8	376	103.0	378
10	111.3	501	110.5	480	105.0	407	105.0	405
11	112.6	529	112.3	513	106.5	432	106.9	439
12	114.0	558	114.0	548	108.3	456	108.5	468
13	115.7	574	115.8	574	110.1	480	110.0	498
14	117.4	596	117.2	596	111.4	503	111.5	527
15	118.8	612	118.5	620	112.7	528	113.0	556
16	120.3	643	119.6	648	113.4	533	114.8	570
17	121.3	660	121.0	675	114.6	553	116.1	584
18	121.8	686	122.0	710	115.6	572	117.4	598
19	122.7	715	122.5	746	116.8	598	118.2	615
20	123.8	747	123.0	788	117.5	621	119.0	632
21	123.9	771	123.5	820	117.9	649	119.5	650
22	124.9	793	124.0	845	119.1	668	120.0	675
23	125.7	811	124.5	870	119.8	689	120.5	700
24	126.5	844	125.0	900	121.0	712	121.0	730

Plate IV.



The relative skeletal growth of normal Holsteins and Jerseys.
Plotted in centimeters - Table 8.

Plate V.



The relative increase in weight of normal Holsteins and Jerseys.
Plotted in pounds - Table 8.

Plate VI.

The average monthly increments in weight of normal Holsteins and Jerseys. - Table 8.

THE EFFECT OF HEAVY AND LIGHT FEEDING ON GROWTH.

It is commonly believed that an animal which is well fed will grow at a more rapid rate than one which receives only a scant ration. The animals upon which this consideration is based were selected from those in the experiment already described. Only those with fairly complete records were considered and the corrections and insertions were made as in the preliminary studies. Calculations were not made for every month, but after eighteen months, values were derived at periods varying from three to twelve months. These values were derived from an average of the values for at least three months for each animal. Thus, if a value was to be secured for the thirty-sixth month, it was represented for each animal by the average of the thirty-fifth, thirty-sixth and thirty-seventh months. In considering the effect of the ration, the early and late-calving animals were grouped together. The results, as regards skeletal growth, need little comment and are represented in Tables 9 and 10, and in Plates VII, VIII, IX, and X. Those animals on the heavy ration invariably made better gains. It will be noted that the heavy-fed animals made greater gains in the early periods and approached maturity at an earlier age than the light-fed ones. It is also interesting that the light-fed animals apparently never attained the size of the others, although they received the same ration after the first calving.

The well known fact that Jerseys become mature at an earlier age than Holsteins is indicated by these figures and the plates which represent them.

The growth as measured by weight is hard to determine and represent. The weights represent the same animals as do the height measurements. Weight is, at best, an unsatisfactory means of measuring growth because of the large daily variations and the variations due to pregnancy and lactation. Weight may be used with some degree of accuracy up to the time at which the animal begins to show the effect of pregnancy, but after that time it is very unsatisfactory. An attempt has been made to overcome this difficulty, at least in part, by taking the weights of all animals up to the age of nineteen months and then taking only the weights directly after parturition, and at a time six months later. The weight of the animal normally drops decidedly directly after partutition, and this loss is not as a rule recovered for several months. At each point of calving the weight is greater than at the preceding point, but it is difficult to determine exactly when the gain is made. The average time of calving for a group was determined and all the values placed at this average month; the next point was set at six months later. The second calving time was treated in the same manner and so on as long as data were available. The other groups were treated in the same way so that if, for example, the average time of first calving of the late-calving group came at thirty-four months and the second calving for the early-calving group at thirty-six months, the average for the two groups would be brought down under the thirty-fifth month. The early values for the late-calving groups were brought down under the values for the early-calving ones. The values are, then, only close approximations, but are believed to be fairly representative of the weights of the animals.

The values given and the plots made are calculated for these average dates. The calculations are shown in Tables 11 and 12, and in Plates XI, XII, XIII, XIV, XV, and XVI. Here again the effect of the ration is well shown. In this case it appears more strongly in the Jerseys than in the Holsteins, if the percentage increments are considered, but this is partly due to the larger difference in the weights of the two groups of Jerseys at the age of one month.

The weight curves are a long distance apart at the age of eighteen to thirty months, but tend to come together as maturity is reached. One thing which is noticeable at the six month point is the decided drop in the curve representing the light-fed group. This is easily accounted for, because it was at this point that these calves were weaned and placed on a ration of hay.

Plates XV and XVI have been plotted according to the second plan outlined in the preliminaries. The values are represented by the amount of the percentage increase over the first measurement. The weights are plotted to the scale at the left and the skeletal measurements to the scale at the right.

At the bottom is a plot representing the increase in the height at withers as it would appear if plotted to the scale to which the weights are plotted. These two plates show plainly two things for each breed -- that the ration has a far greater effect upon the weight of the animal than upon the skeletal growth, and that the weight-increase continues for a long time after the skeletal growth seems to be complete. The decided drop at the age of six months is to be seen here also in the light-fed animals. Such a drop would not be expected in the heavy-fed animals because they were placed on a heavy ration as soon as they were weaned.

In order to show the effect of the ration in another way, the heavy-fed and the light-fed animals in both breeds were compared with the new normal breed values. At nearly every point the normals for height and for weight were between the values for the heavy and light-fed animals. Exceptions occur at several points in the height and weight of the Jerseys. In this group the normals were ahead of the heavy-fed animals for a time. This condition may be accounted for by the unthrifty condition of some of the Jerseys in early life. The represen-tation of these conditions may be seen in Tables 13 and 14, and in Plates XVII, XVIII, XIX, and XX.

The animals in the normal groups have not all reached the age of thirty months, and the values for the twenty-seventh and thirtieth months in Tables 13 and 14 are based on that part of the group which have reached that age.

TABLE 9.

HEAVY VS. LIGHT FED HOLSTEINS.

HEIGHT AT WITHERS

Age in months	Heavy Fed: Ht. at withers Cm.	Heavy Fed: Amt. Inc. over 1st. meas. %	Heavy Fed: Amt. mo. inc. Cm.	Light Fed: Ht. at withers Cm.	Light Fed: Amt. Inc. over 1st. meas. %	Light Fed: Amt. mo. inc. Cm.
1	76.7			75.6		
2	81.7	6.5	5.0	80.4	6.3	4.8
3	88.1	14.8	6.4	84.6	11.9	4.2
4	93.6		5.5	88.6		4.0
5	99.7		6.1	93.7		5.1
6	103.4	34.8	3.7	96.7	27.9	3.0
7	106.2			98.2		
8	108.7			99.7		
9	111.5	45.3	2.7	101.2	33.8	1.5
10	113.5			102.7		
11	115.8			104.5		
12	117.8	53.5	2.1	106.3	40.6	1.66
13	119.2			107.6		
14	120.8			109.2		
15	122.3	59.4	1.5	110.8	46.5	1.5
16	123.8			113.0		
17	124.9			113.8		
18	125.4	63.5	1.03	115.3	52.5	1.5
19	126.9			116.6		
20	127.9			117.4		
21	128.5	67.5	1.03	118.6	56.8	1.1
22	129.1			119.7		
23	129.5			121.1		
24	130.1	69.6	.53	121.6	60.8	1.0
27	131.6	71.5	.5	123.9	63.8	.76
30	132.6	72.8	.3	125.6	66.1	.56
36	133.7	74.3	.18	126.9	67.8	.21
42	134.7	75.6	.16	128.5	70.0	.26
48	134.9	75.8	.03	129.5	71.3	.16
60	135.9	77.2	.08	130.3	72.3	.06

TABLE 10.

HEAVY VS. LIGHT FED JERSEYS.

HEIGHT AT WITHERS.

	Heavy Fed			Light Fed		
Age in months	Ht. at withers Cm.	Amt. Inc. over 1st. meas. %	Amt. mo. inc. Cm.	Ht. at withers Cm.	Amt. inc. over 1st. meas. %	Amt. mo. inc. Cm.
1	70.1			71.6		
2	73.1	4.2	3.0	75.9	6.0	4.3
3	77.9	11.1	4.8	80.5	12.4	4.6
4	83.6		5.7	84.2		3.7
5	88.6		5.0	87.9		3.7
6	92.7	32.2	4.1	92.3	28.9	4.4
7	96.5			93.9		
8	99.4			95.2		
9	102.2	45.8	3.16	97.2	35.7	1.63
10	105.0			99.1		
11	107.3			101.4		
12	108.8	55.2	2.2	102.5	43.1	1.76
13	110.7			103.9		
14	112.4			105.3		
15	114.2	62.9	1.8	106.3	48.4	1.26
16	114.5			107.8		
17	115.7			109.2		
18	116.6	66.3	.8	110.6	54.4	1.43
19	118.8			112.3		
20	119.8			113.2		
21	120.5	71.9	1.3	114.1	59.3	1.16
22	120.9			114.9		
23	121.4			115.9		
24	121.8	73.7	.43	116.3	62.4	.73
27	123.1	75.6	.43	117.6	64.2	.43
30	124.2	77.1	.4	119.5	66.9	.63
36	125.1	78.4	.15	121.9	70.2	.4
42	125.4	78.8	.05	121.9	70.2	.0
48	125.7	79.3	.05	123.0	71.7	.18
60	125.9	79.6	.01	123.0	71.7	.0

TABLE 11

HEAVY VS. LIGHT FED HOLSTEINS.

WEIGHT

	Heavy Fed			Light Fed		
Age in Months	Pounds	Amt. Inc. over 1st. wt. in %	Amt. mo. inc. pounds	Pounds	Amt. Inc. over 1st. wt. in %	Amt. mo. inc. pounds
1	113			104		
2	139	23	26	137	31	33
3	212	87	73	177	70	40
4	263			214		
5	362			258		
6	418	270	69	292	180	38
7	455			307		
8	490			326		
9	545	382	42	344	230	17
10	591			372		
11	628			382		
12	659	483	38	404	288	20
13	714			431		
14	737			463		
15	776	586	39	491	372	29
16	819			519		
17	852			535		
18	891	688	38	569	447	26
19	932			588		
21	938	730	16	666	540	32
22	1036	816	16	745	616	13
34	1094	868	8	866	732	17
40	1070	847	- 4	883	749	3
48	1122	892	6	946	809	8
54	1119	890	0	968	830	4

TABLE 12

HEAVY VS. LIGHT FED JERSEYS.

WEIGHT.

Age in months	Heavy Fed Pounds	Heavy Fed Amt. Inc. over 1st. Wt. in %	Heavy Fed Amt. mo. inc.	Light Fed Pounds	Light Fed Amt. Inc. over 1st. Wt. in %	Light Fed Amt. mo. inc. pounds
1	66			87		
2	88	33	22	109	25	22
3	119	80	31	137	57	28
4	161			173		
5	203			211		
6	246	275	43	245	181	36
7	285			261		
8	321			279		
9	357	440	36	295	239	17
10	393			312		
11	436			336		
12	463	601	35	363	317	23
13	504			378		
14	540			404		
15	579	777	39	431	395	23
16	628			455		
17	667			477		
18	708	972	43	495	469	21
19	745			514		
22	770	1066	26	571	556	19
28	830	1157	10	677	678	18
34	860	1203	5	742	752	11
40	875	1226	2	752	764	2
46	894	1254	3	799	818	8
54	894	1254	0	823	846	3

TABLE 13

HEAVY AND LIGHT FED ANIMALS COMPARED WITH NORMALS

HOLSTEINS.

Age in Months	Height at Withers: Light Fed	Height at Withers: Normal	Height at Withers: Heavy Fed	Weight in Pounds: Light Fed	Weight in Pounds: Normal	Weight in Pounds: Heavy Fed
1	75.6	76.8	76.7	104	121	113
2	80.4	82.0	81.7	137	157	138
3	84.6	86.8	88.1	177	200	212
4	86.6	92.0	92.2	214	249	263
5	93.7	96.5	99.7	258	302	362
6	96.7	100.9	103.4	292	349	418
7	98.2	104.0	106.2	307	389	455
8	99.7	107.1	108.7	326	425	490
9	101.2	109.1	111.5	344	466	545
10	102.7	111.3	113.5	372	501	591
11	104.5	112.6	115.8	382	529	628
12	106.3	114.0	117.8	404	558	659
13	107.6	115.7	119.2	431	574	714
14	109.2	117.4	120.8	463	596	737
15	110.8	118.8	122.3	491	612	776
16	113.0	120.3	123.8	519	643	819
17	113.8	121.3	124.9	535	660	852
18	115.3	121.8	125.4	569	686	891
19	116.6	122.7	126.9	588	715	932
20	117.4	123.8	127.9		747	
21	118.6	123.9	128.5	666	771	938
22	119.7	124.9	129.1		793	
23	121.1	125.7	129.5		811	
24	121.6	126.5	130.1		844	
27	123.9	129.3	131.6	745	940	1036
30	125.6	130.9	132.6		1036	

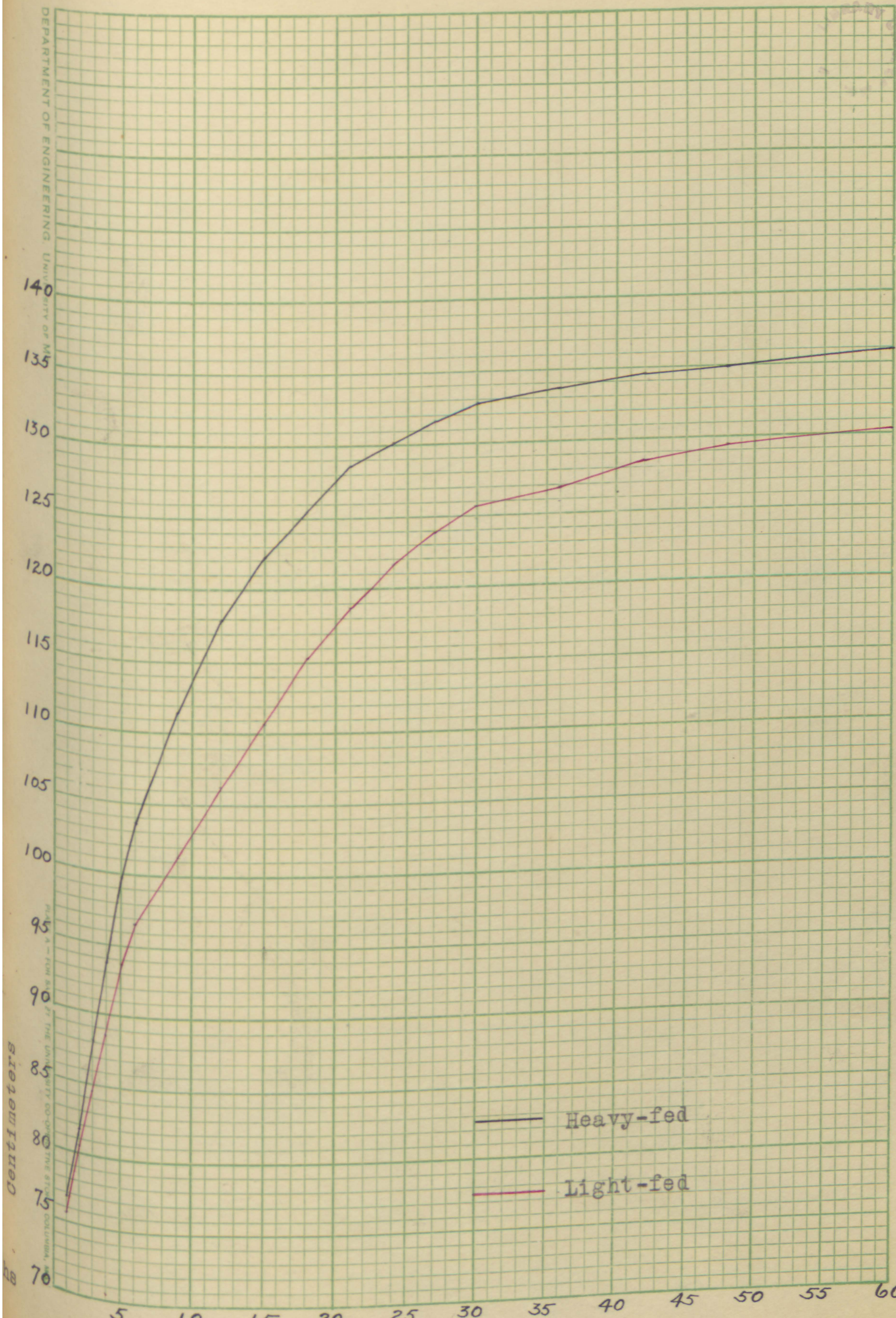
TABLE 14

HEAVY AND LIGHT FED ANIMALS COMPARED WITH NORMALS.

JERSEYS

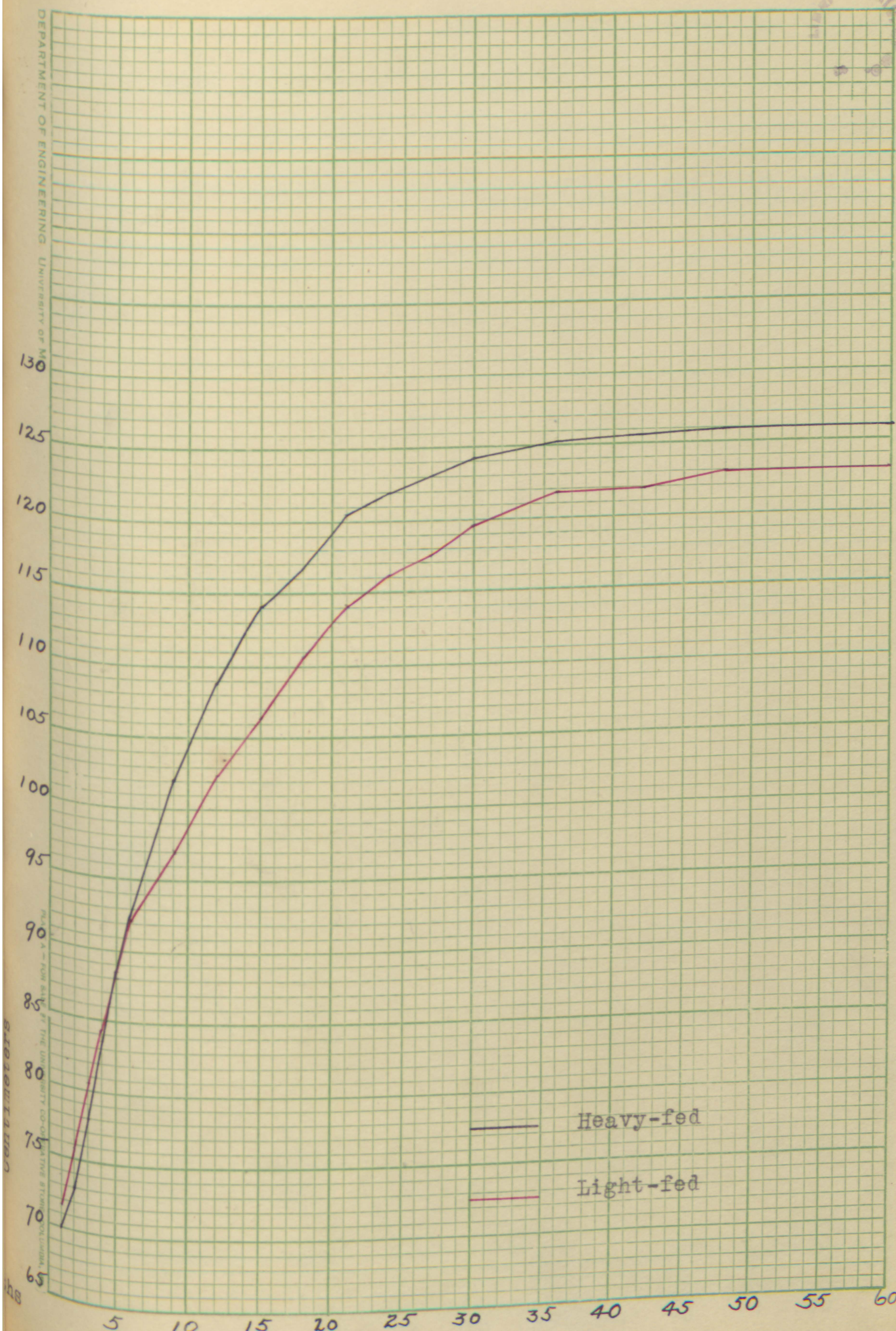
Age in Months	Height at Withers			Weight in Pounds		
	Light Fed	Normal	Heavy Fed	Light Fed	Normal	Heavy Fed
1	71.6	70.3	70.1	87	76	66
2	75.9	74.7	73.1	109	105	88
3	80.5	79.3	77.9	137	140	119
4	84.2	83.9	83.6	173	174	161
5	87.9	89.3	88.6	211	222	203
6	92.3	93.7	92.7	245	260	248
7	93.9	96.8	96.5	261	302	285
8	95.2	99.8	99.4	279	340	321
9	97.2	102.8	102.2	295	376	357
10	99.1	105.0	105.0	312	407	393
11	101.4	106.5	107.3	336	432	436
12	102.5	108.3	108.8	363	456	463
13	103.9	110.1	110.7	378	480	504
14	105.3	111.4	112.4	404	503	540
15	106.3	112.7	114.2	431	528	579
16	107.8	113.4	114.5	455	533	628
17	109.2	114.6	115.7	477	553	667
18	110.6	115.6	116.6	495	572	708
19	112.3	116.8	118.8	514	598	745
20	113.2	117.5	119.8		621	
21	114.1	117.9	120.5		649	
22	114.9	119.1	120.9	571	668	770
23	115.9	119.8	121.4		689	
24	116.3	121.0	121.8		712	
27	117.6	122.9	123.1	677	770	830
30	119.5	123.5	124.2		812	

Plate VII.



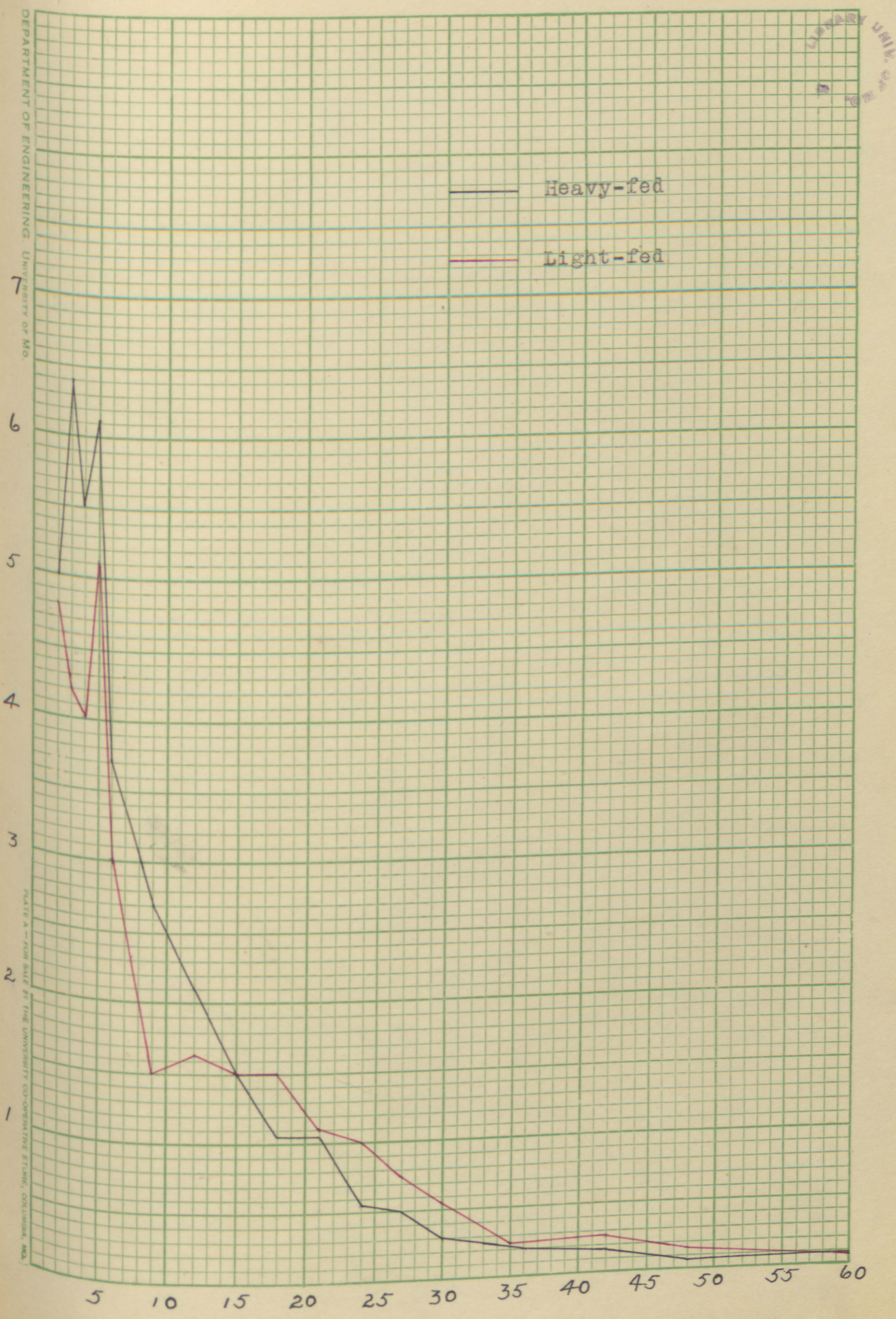
Height at withers of heavy vs light-fed Holsteins.
Plotted directly in centimeters. - Table 9.

Plate VIII.



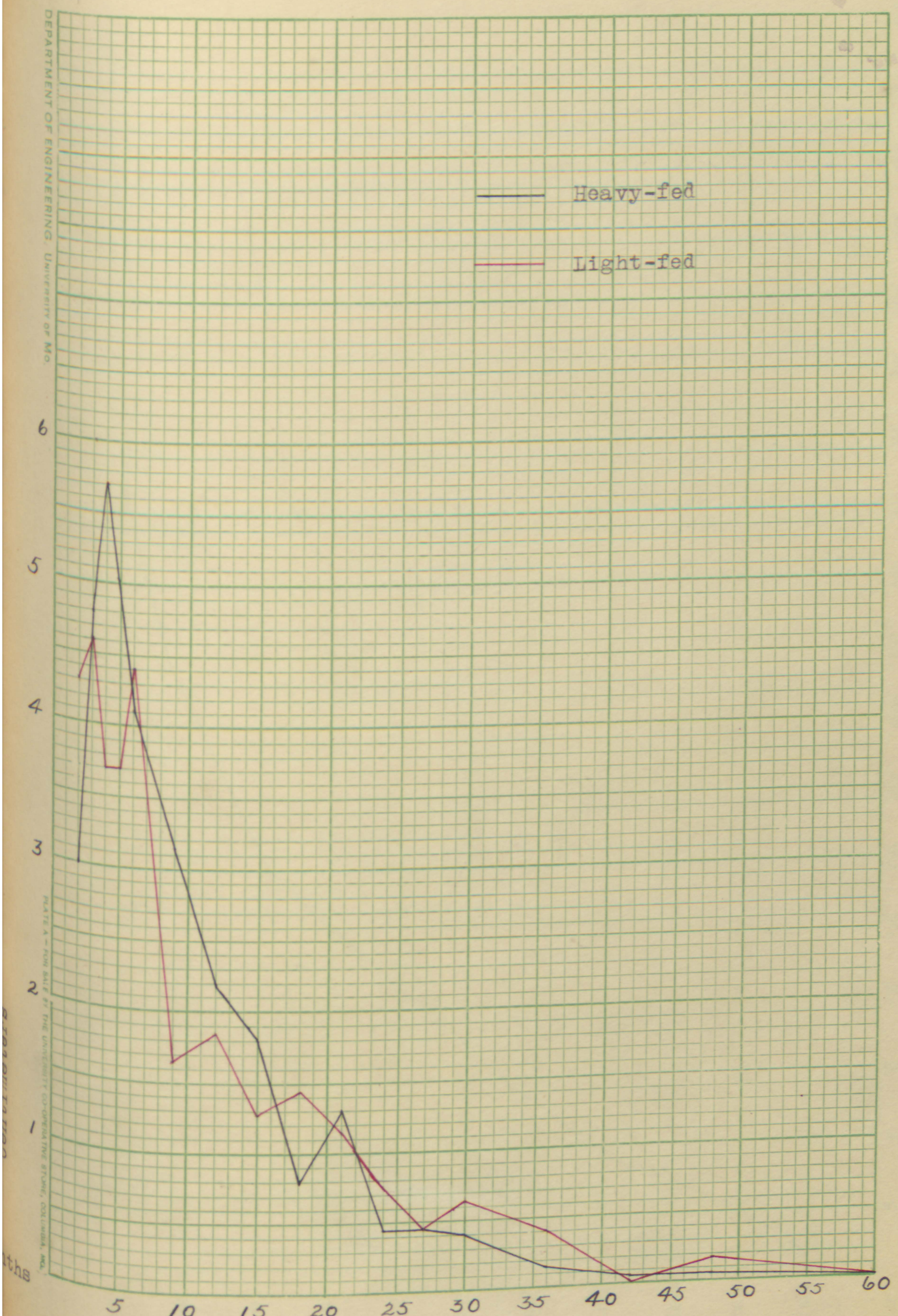
Height at withers of heavy vs light-fed Jerseys.
Plotted directly in centimeters.- Table 10.

Plate IX.

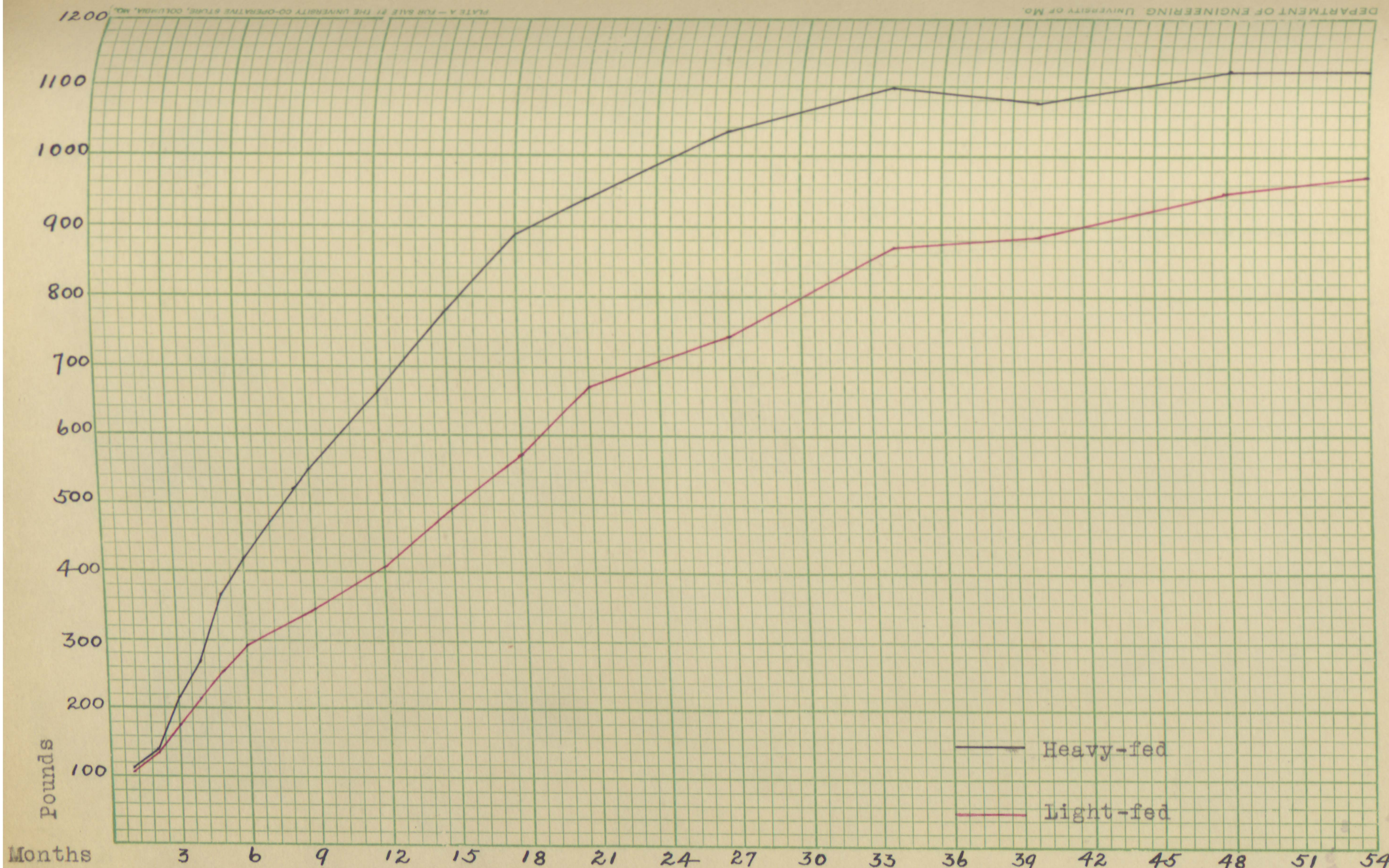


The average monthly increase in height at withers of heavy vs light-fed Holsteins. - Table 9.

Plate X.



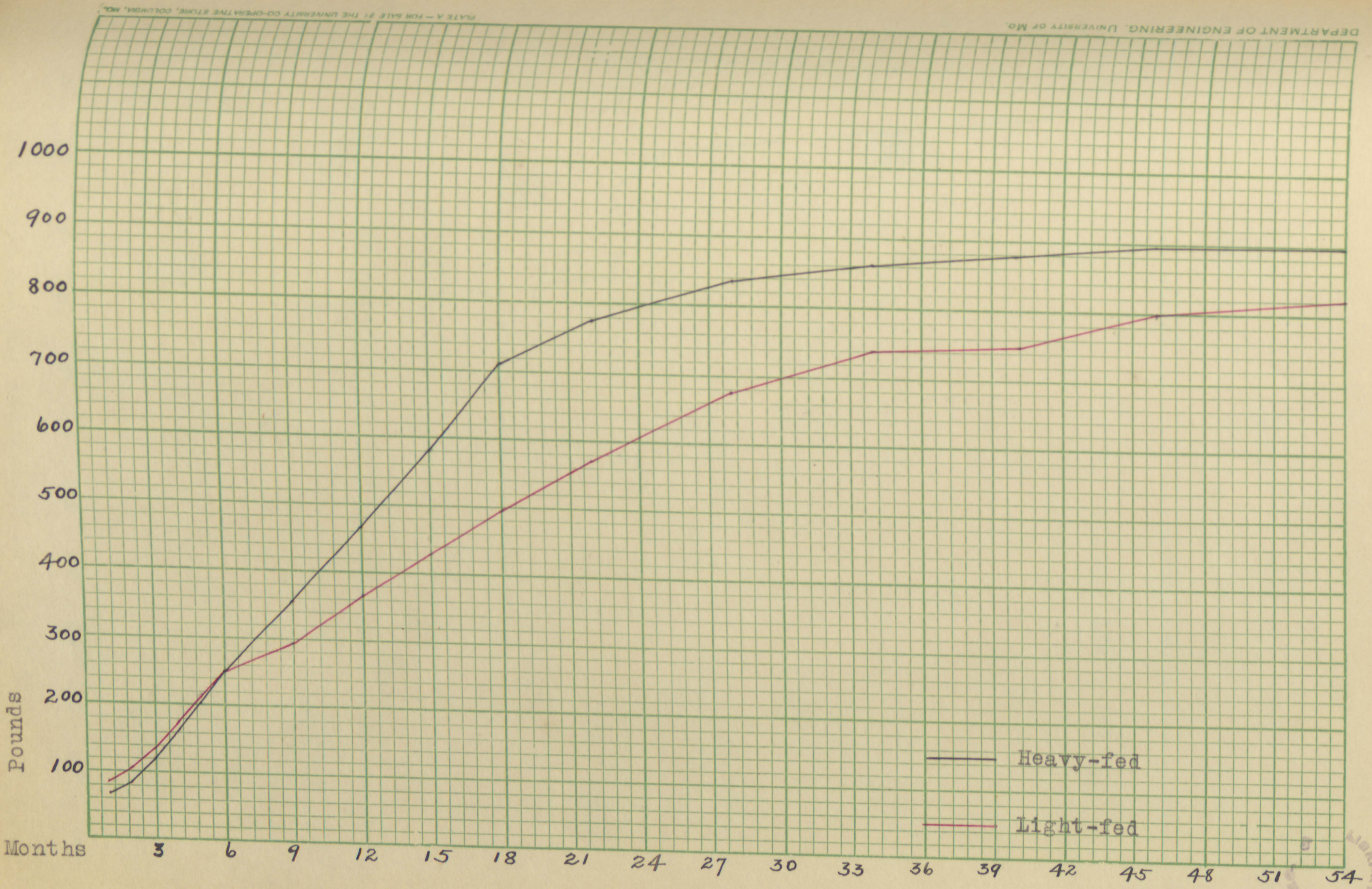
The average monthly increase in height at withers
of heavy vs light-fed Jerseys. - Table 10.



Weights of heavy vs light-fed Holsteins.
Plotted directly in pounds. Table 11.

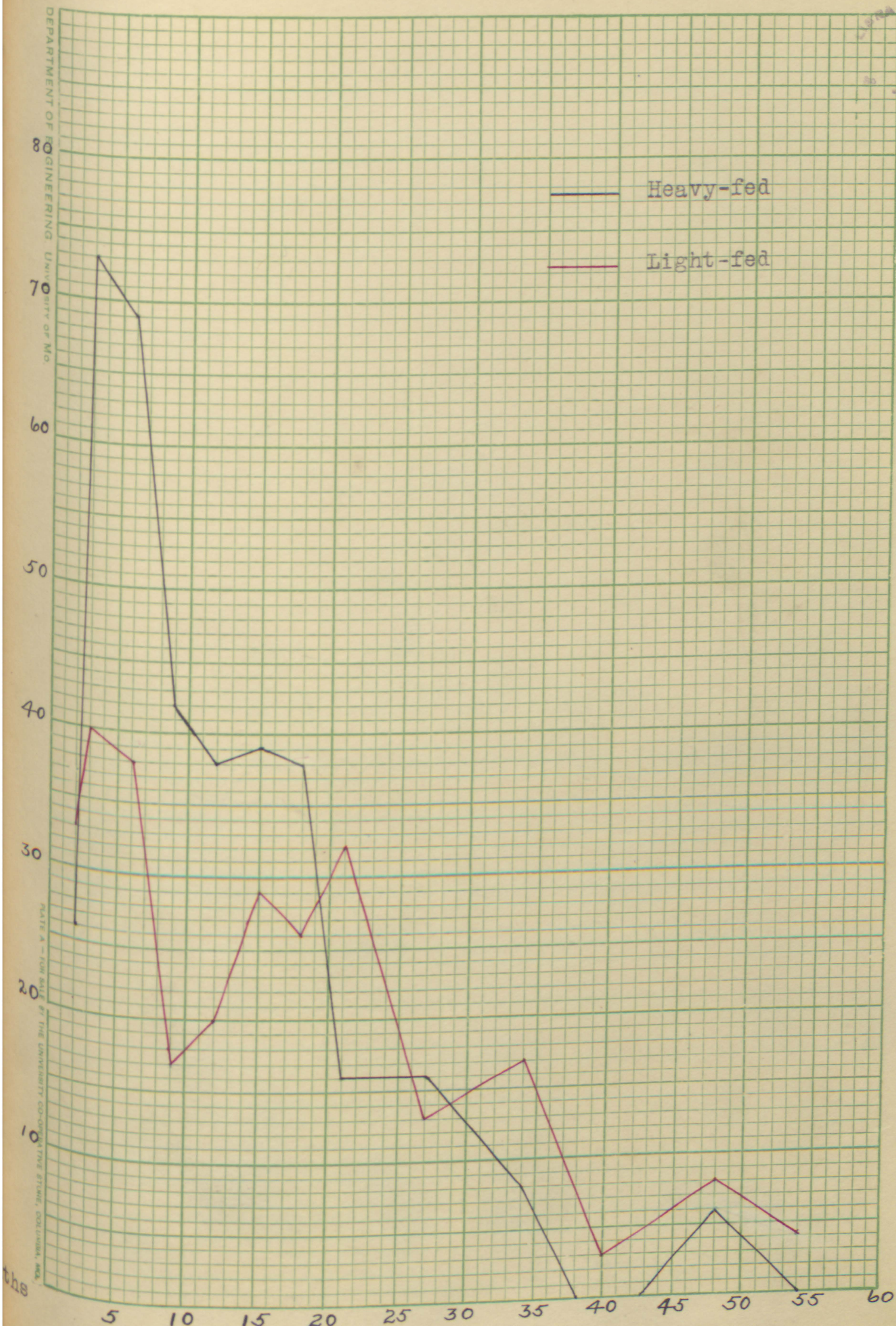
Plate XI.

Plate XII.



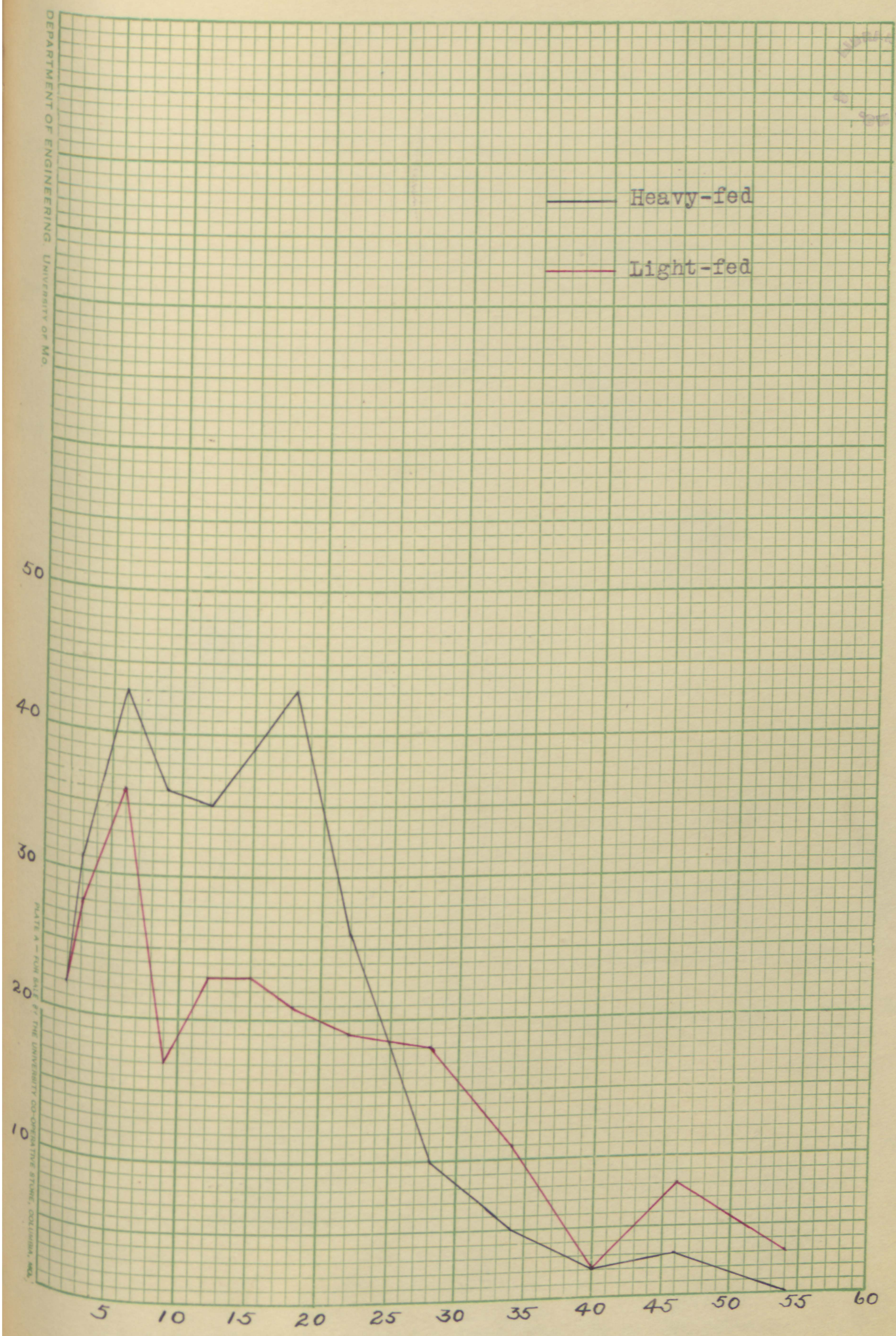
Weights of heavy vs light-fed Jerseys. Plotted directly in pounds. - Table 12.

Plate XIII.



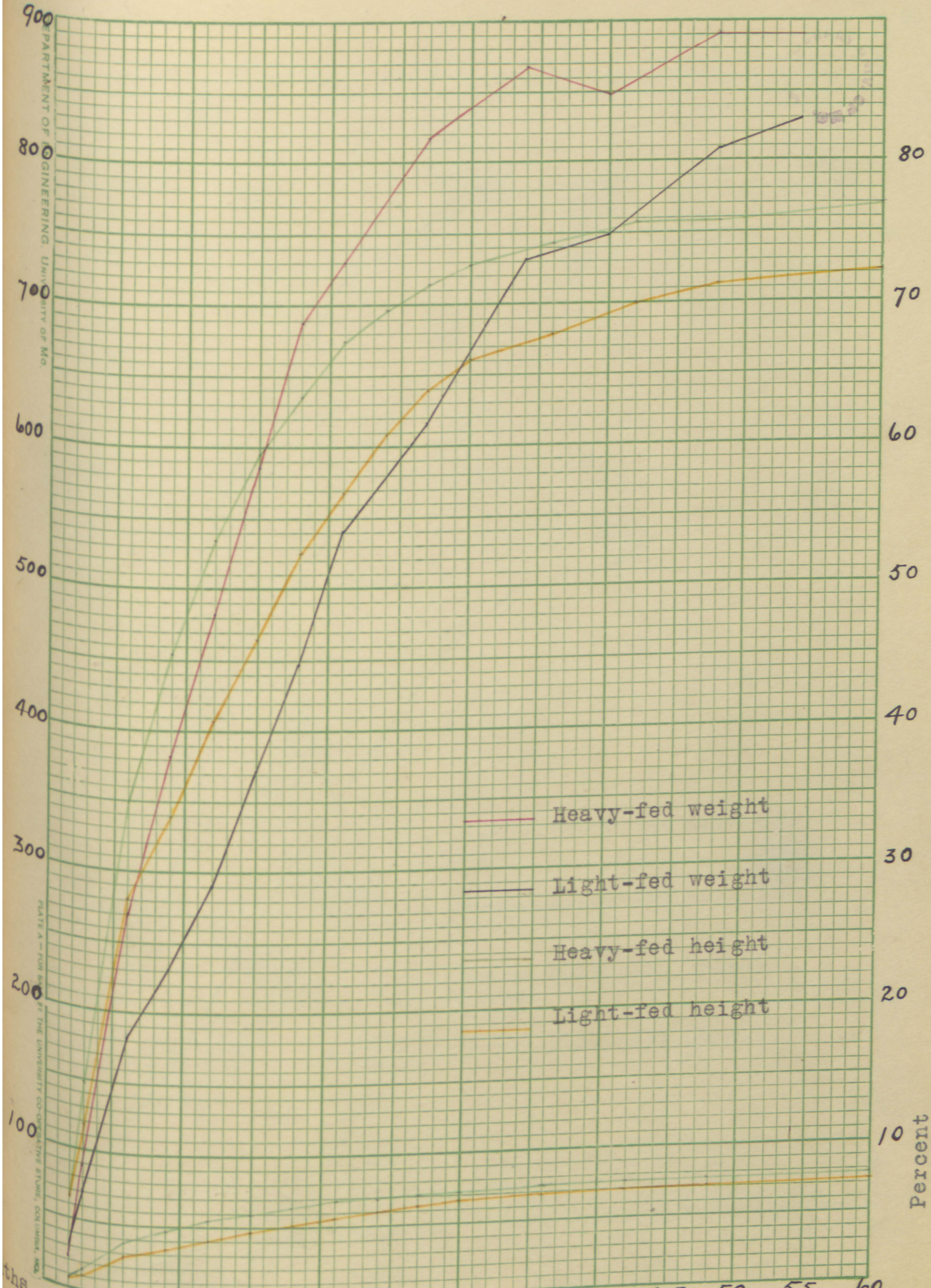
The average monthly increments in weight of heavy vs light-fed Holsteins. - Table 11.

Plate XIV.



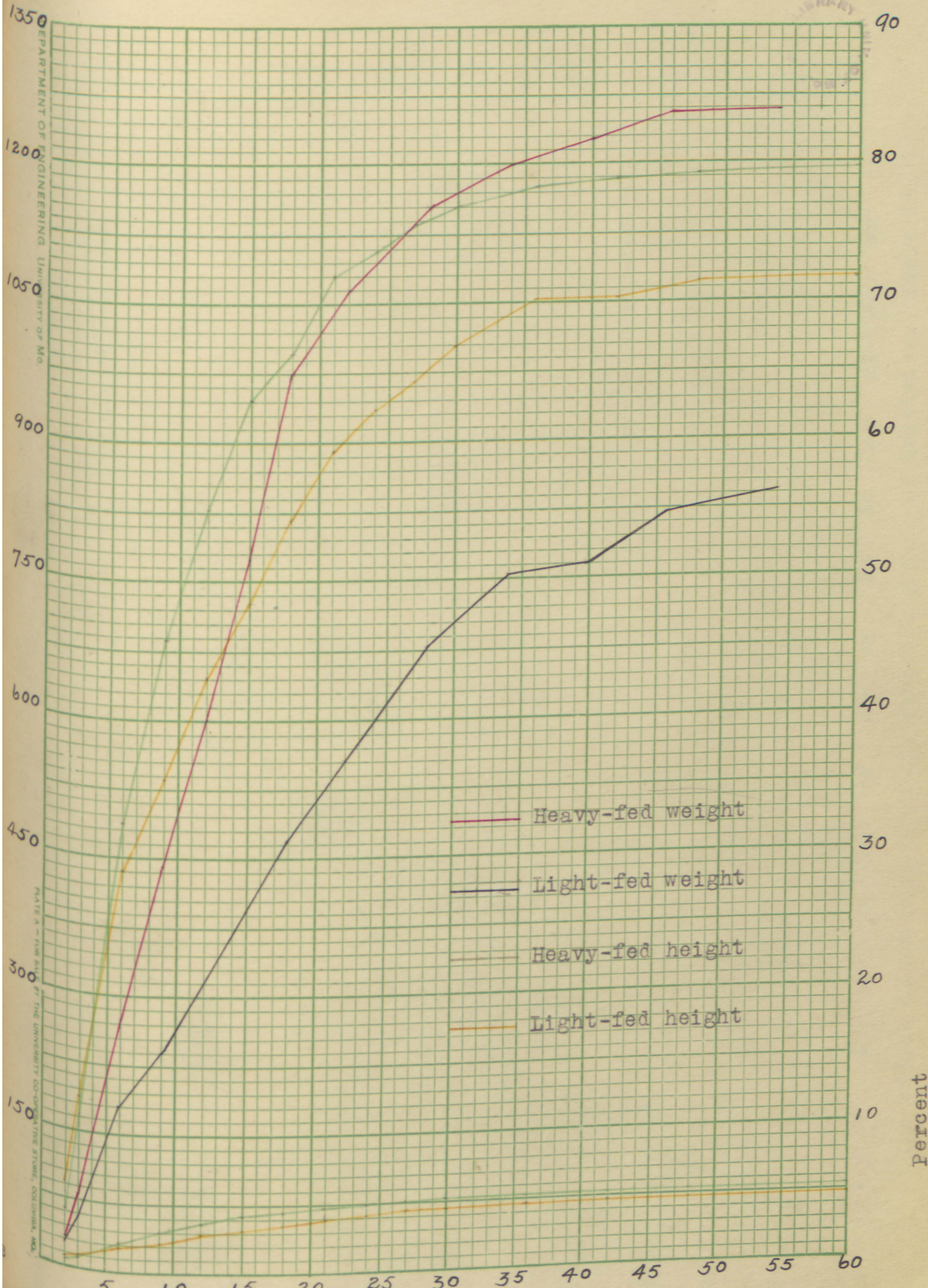
The average monthly increments in weight of heavy vs light-fed Jerseys. - Table 12.

Plate XV.



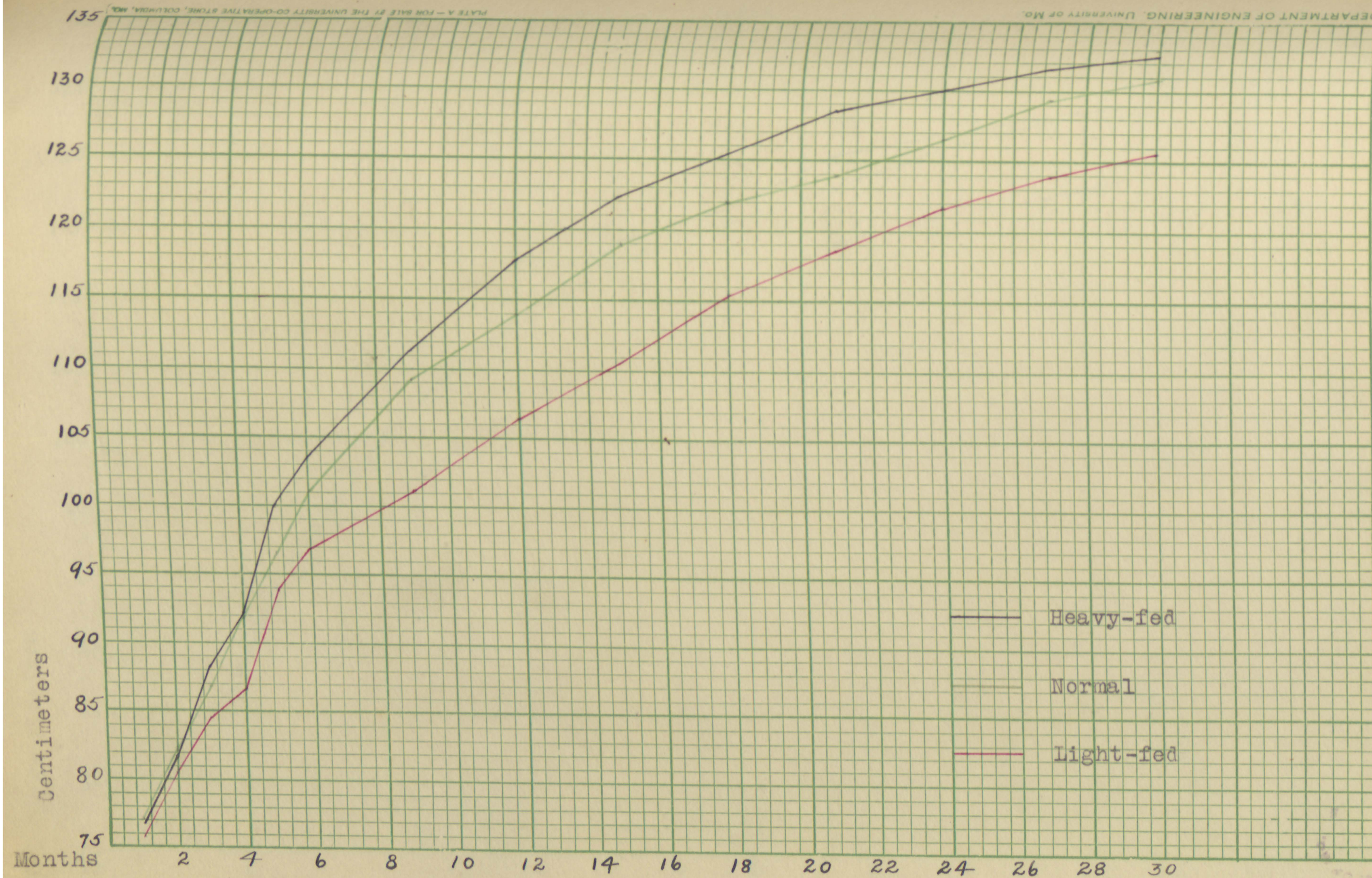
The percentage increments over the first measurement, of height and weight of heavy vs light-fed Holsteins.
Weight increments - scale at left.
Height increments - scale at right.

Plate XVI.



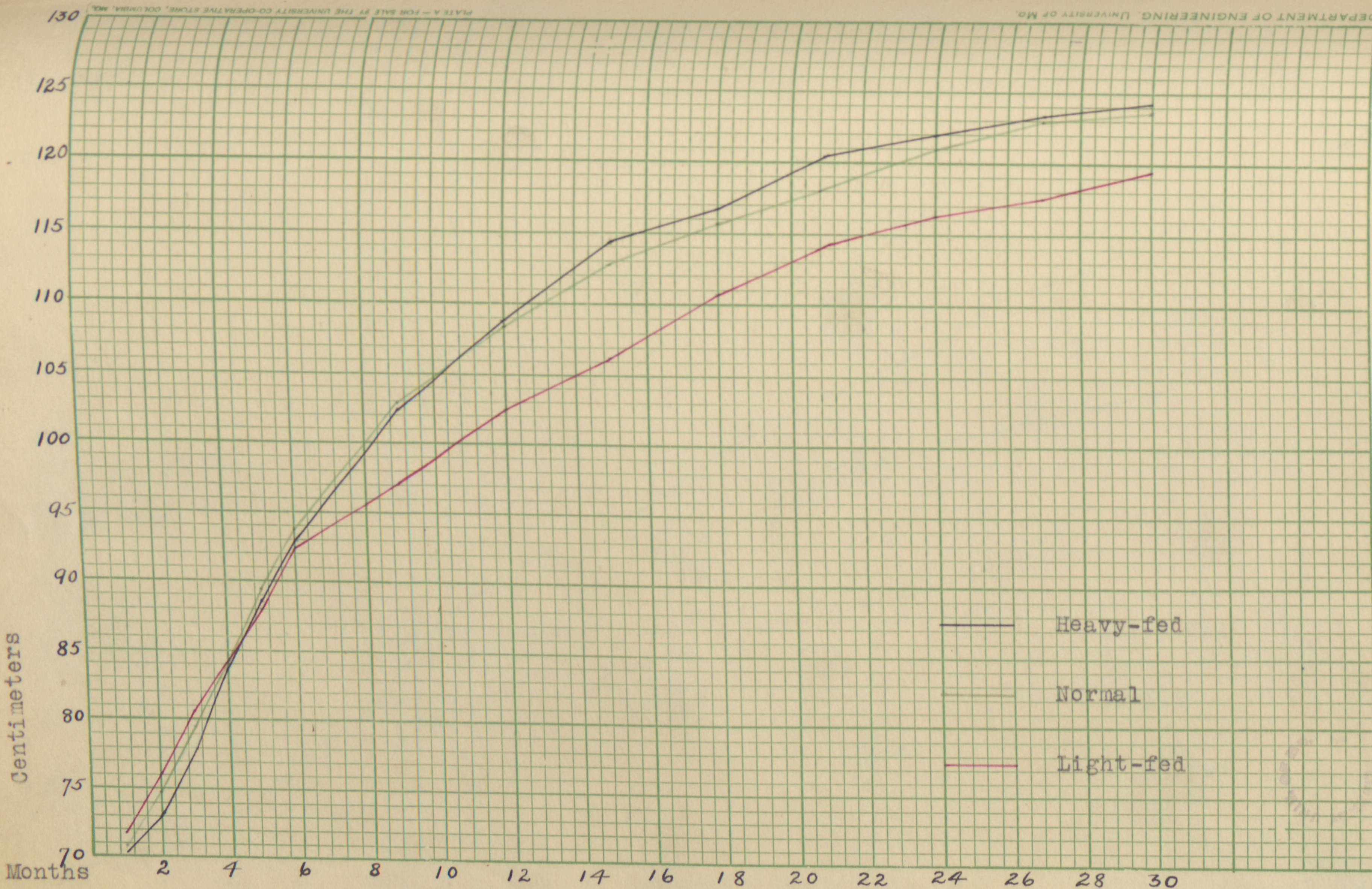
The percentage increments over the first measurement of height and weight of heavy vs light-fed Jerseys.
Weight increments - scale at left.
Height increments - scale at right.

Plate XVII.

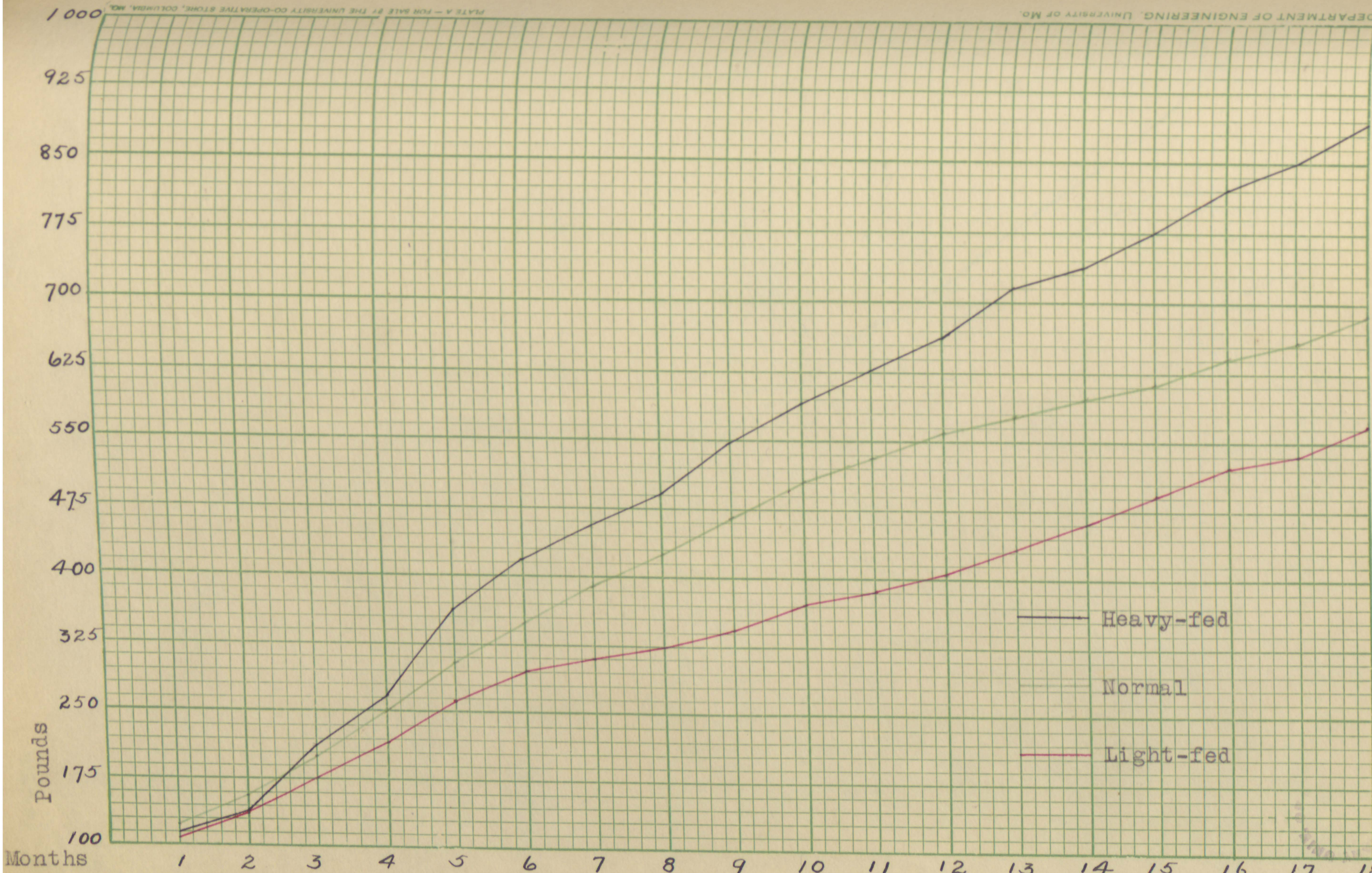


The effect of the ration on the skeletal growth of Holsteins. Table 13.
Plotted directly in centimeters.

Plate XVIII.



The effect of the ration on the skeletal growth of Jerseys. Table 14.
Plotted directly in centimeters.

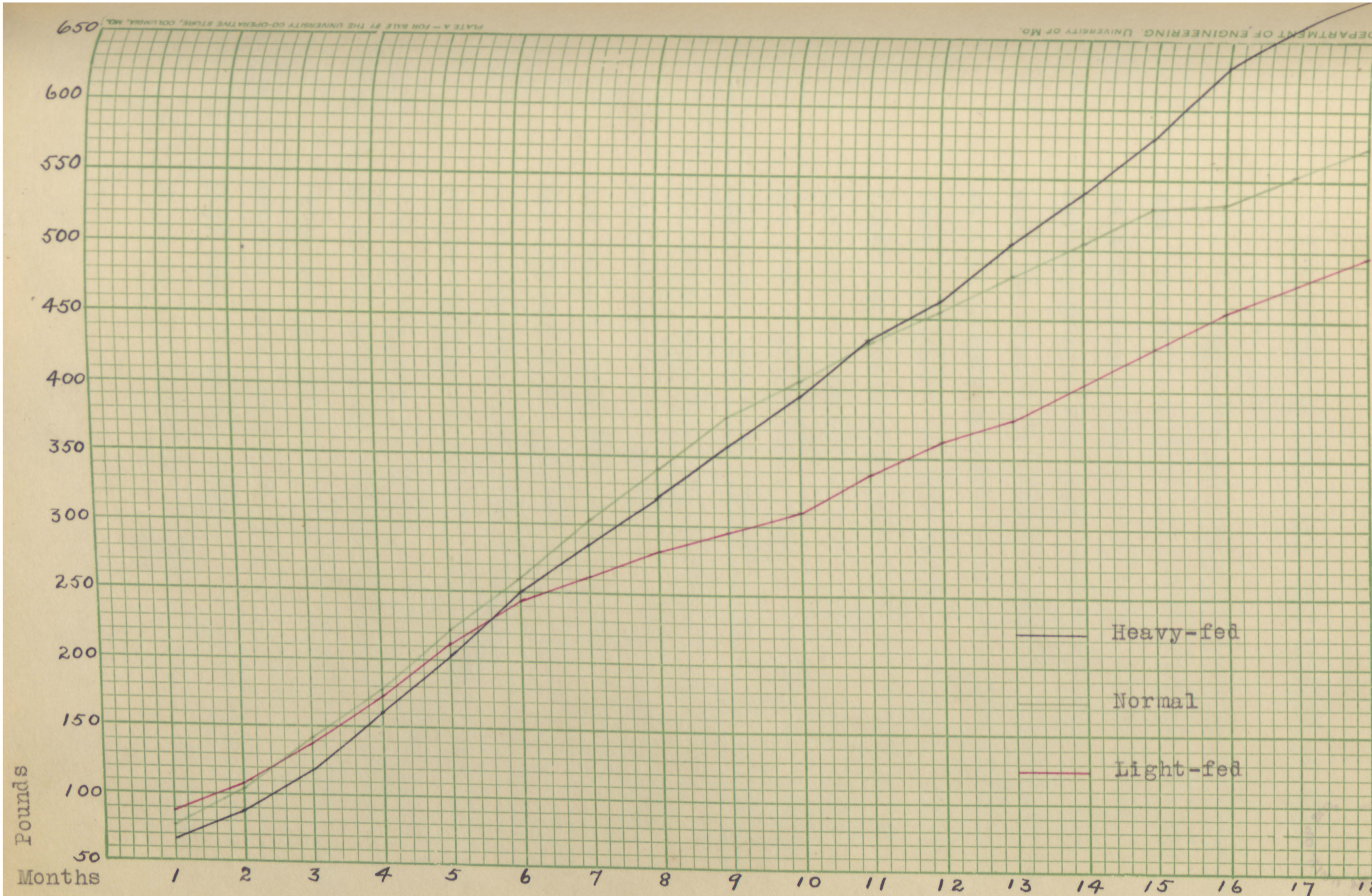


The effect of the ration on the increase in weight of Holsteins. Table 13.

Plotted directly in pounds.

Plate XIX.

Plate XX.



The effect of the ration on the increase in weight of Jerseys. Table 14.
Plotted directly in pounds.

THE EFFECT OF EARLY AND LATE CALVING ON GROWTH

In order to determine the effect of early and late-calving upon the development of the animals concerned, the averages for the early and late-calving groups were plotted and compared. The plot was started at nineteen months because it seemed that pregnancy could have had no appreciable effect upon growth at that point. The values were taken for the same points which were used in considering the effect of the ration. The comparison was made for the heavy-fed Holsteins and for the heavy-fed and light-fed Jerseys. The light-fed Holsteins were not evenly divided and a fair comparison could not be made. Both height at withers and weights were used in the consideration. The results are shown in Tables 15, 16, 17 and 18, and in Plates XXI, XXII, and XXIII. A consideration of the figures and plots, immediately shows the effect of the time of calving upon the skeletal growth of the animals. In every case those in the late-calving groups were somewhat ahead at the age of five years, while at the age of nineteen months they were close together. The least effect was shown on the light-fed Jerseys. The figures and plots need little comment and will not be discussed further.

All the work which has been done relating to the effect of pregnancy and lactation indicates that pregnancy has little effect, while lactation has a pronouneed effect upon growth. It is to be assumed, then, that the detrimental effect of early calving herein noted was due to the strain of lactation. The production of milk seems to be an impulse or tendency which is even stronger than the "inherent tendency to grow".

TABLE 15

EARLY VS. LATE CALVING HOLSTEINS.

HEIGHT AT WITHERS.

HEAVY FED

Age in months	Early Calving	Late Calving
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

TABLE 16

WEIGHT

19	942	922
21	883	994
27	888	1184
34	963	1225
40	1011	1129
48	1105	1139
54	1118	1121

TABLE 17

EARLY VS. LATE CALVING JERSEYS

HEIGHT AT WITHERS

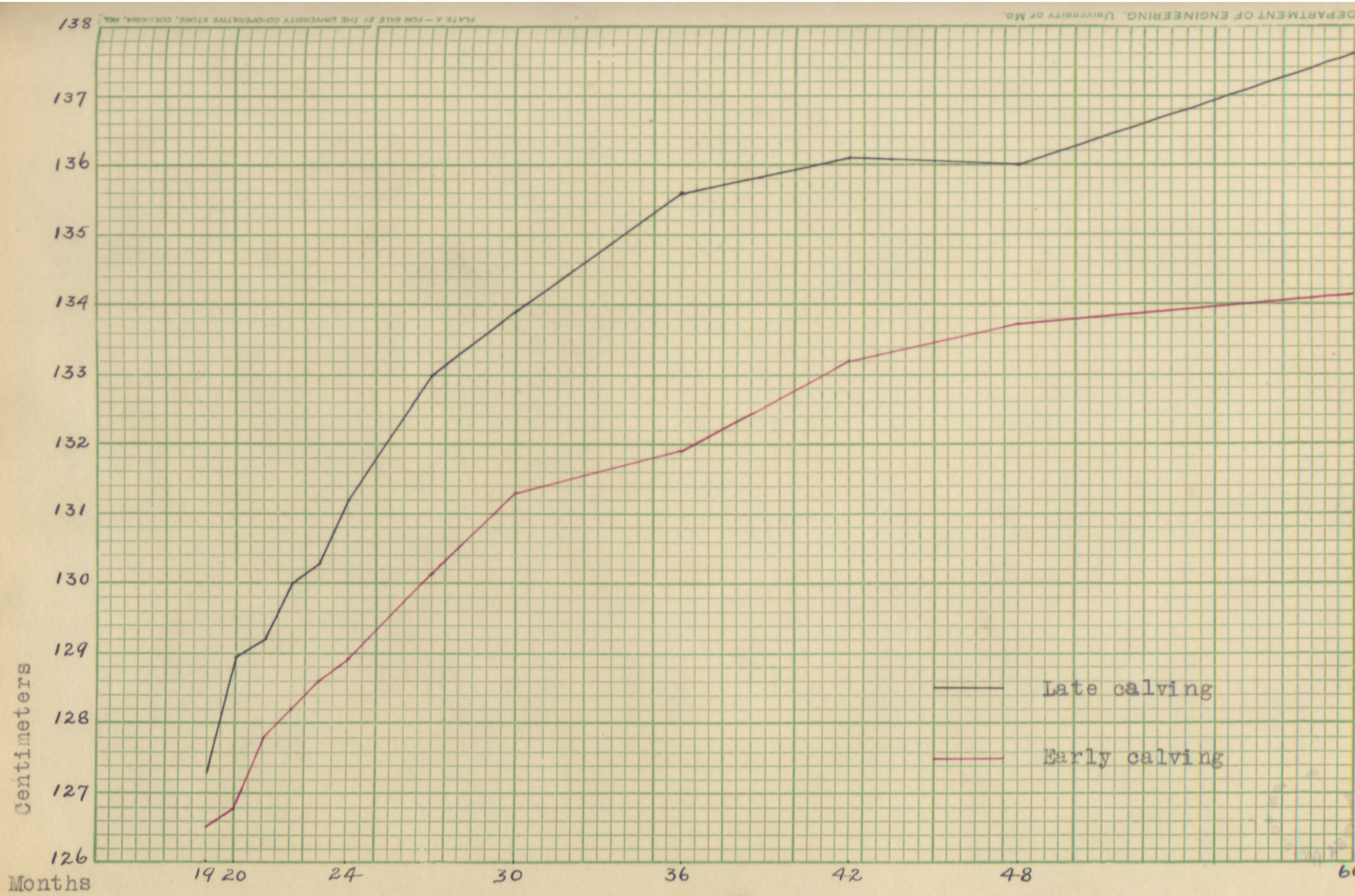
Age in Months	Heavy Fed		Light Fed	
	Early Calving	Late Calving	Early Calving	Late Calving
19	119.5	118.1	111.1	113.6
20	120.5	119.1	112.2	114.3
21	120.7	120.3	112.4	115.8
22	121.4	120.4	113.4	116.4
23	121.5	121.3	114.4	117.4
24	121.6	122.0	114.8	117.8
27	122.6	123.7	115.6	119.7
30	124.0	124.5	117.1	122.0
36	124.1	126.1	119.6	124.2
42	124.6	126.3	119.8	124.1
48	124.7	127.0	121.4	124.6
60	124.7	127.2	121.3	124.6

TABLE 18

EARLY VS. LATE CALVING JERSEYS

WEIGHT

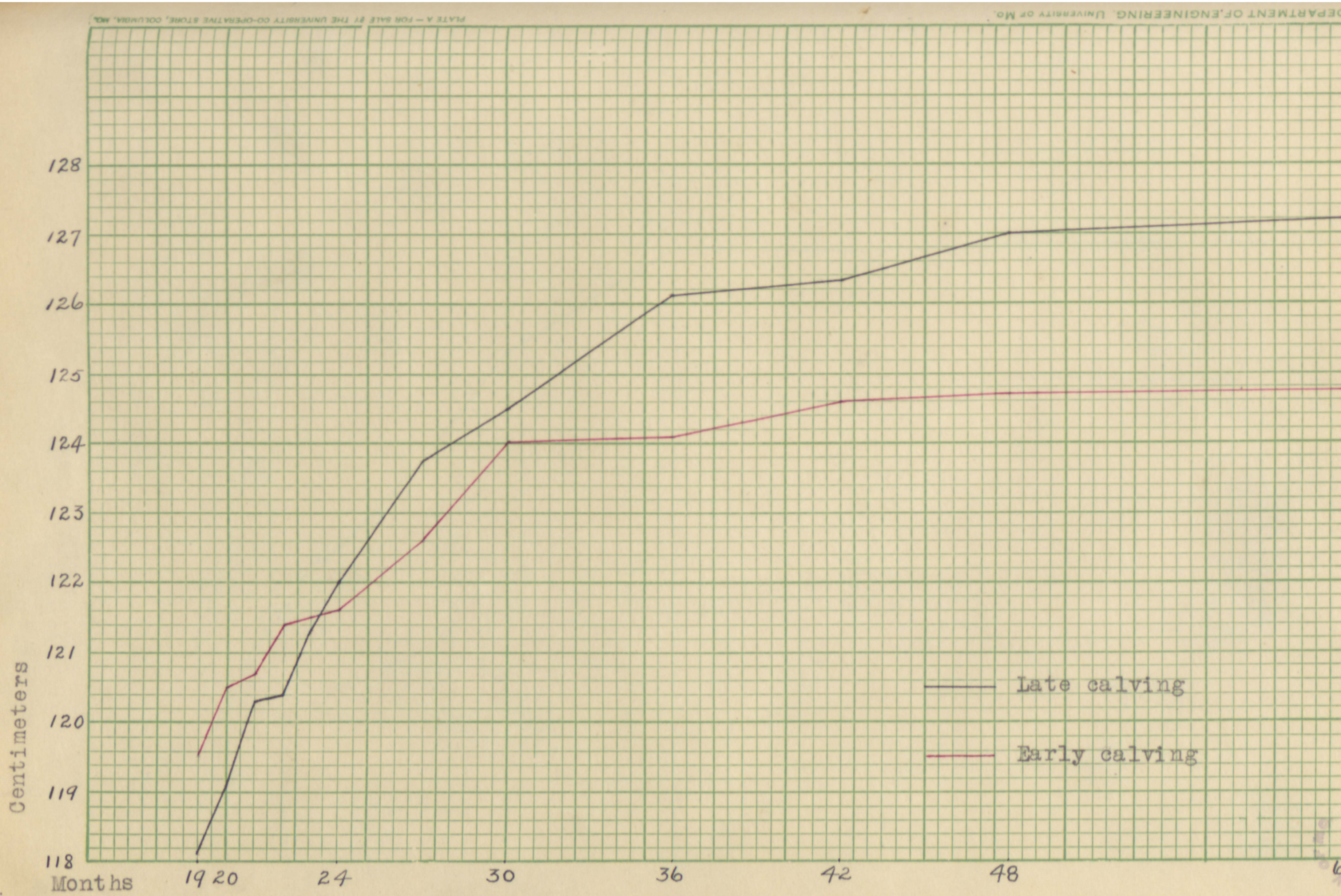
Age in Months	Heavy Fed		Light Fed	
	Early Calving	Late Calving	Early Calving	Late Calving
19	759	732	504	524
22	758	782	556	587
28	726	934	614	740
34	740	981	687	806
40	839	911	705	800
46	850	937	773	827
54	864	924	763	882



The effect of early vs late calving on the skeletal growth of heavy-fed Holsteins. Table 15. Plotted directly in centimeters.

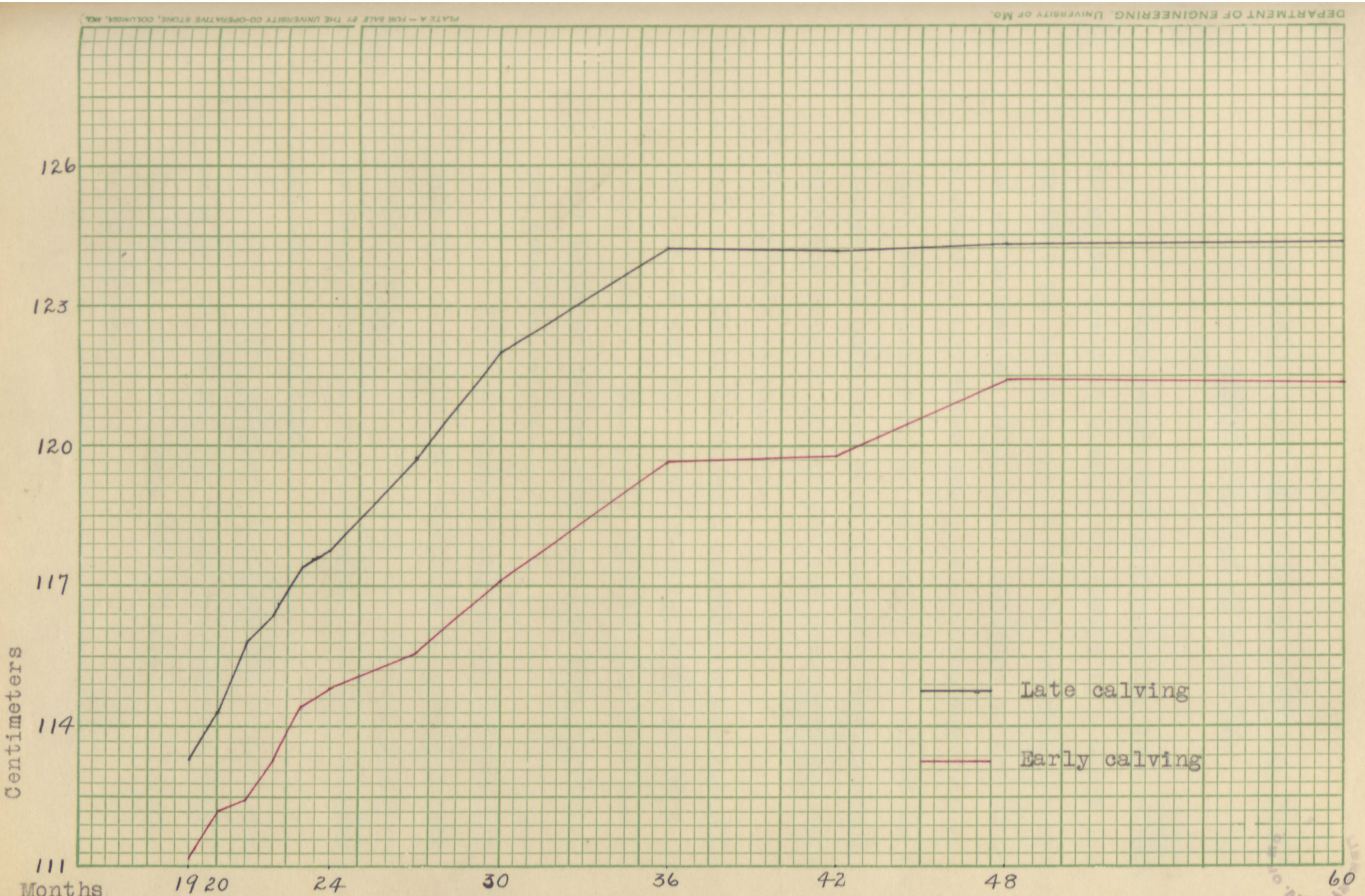
Plate XXI.

Plate XXII.



The effect of early vs late calving on the skeletal growth of heavy-fed Jerseys. Table 17. Plotted directly in centimeters.

Plate XXIII.



The effect of early vs late calving on the skeletal growth of light-fed Jerseys.
Table 17. Plotted directly in centimeters.

THE BIRTH WEIGHT OF CALVES AS AFFECTING THEIR GROWTH AND SIZE AT MATURITY.

Many people are of the belief that a calf which is small at birth will result in a small cow, or that the birth-weight tends to determine the size of the animal at maturity. In order to determine whether or not there are good grounds for this belief, the birth-weights of some of the calves in the University herd have been considered and compared with the rate of growth and the size of these same individuals at maturity.

Table 19 shows a comparison between animals No. 2 and No. 17 which weighed 35 and 67 pounds respectively. The small calf in this case has become as large as the other and has even surpassed the other in weight.

Table 20 shows a comparison between animals No. 41 and No. 53, weighing 32 and 60 pounds respectively. In this case the reverse condition is found, for the smaller animal at birth remains the smaller through life.

Table 21 gives a comparison between animals No. 48 and No. 59, weighing 55 pounds each. The development of these two animals is outstandingly different.

Tables 22 and 23 represent the development of normal individuals of the Holstein and Jersey breeds up to the age of twenty-four months. The Jerseys show a very slight correlation between birth-weight and growth, while the Holsteins show practically the reverse condition.

Table 24 consists of the birth-weights and height at withers at maturity of all the animals of the University herd for which such data are available. In this case the Jerseys show no direct correlation, while the Holsteins on an average seem to show a slight one between birth-weight and size at maturity. It seems safe to assume that, in general, there is no correlation between the birth-weight and the growth or the size at maturity of dairy animals.

TABLE 19

A STUDY OF INDIVIDUAL BIRTH WEIGHTS

Age in: Months	Cow No. 2 Weight	Cow No. 2 Height	Cow No. 17 Weight	Cow No. 17 Height
Birth	35		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

TABLE 20

	Cow No. 41		Cow No. 53	
Birth	32		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

TABLE 21

	Cow No. 48		Cow No. 59	
Birth	55		55	
19	538	111.5	453	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 22.

RELATION OF BIRTH WEIGHT TO GROWTH IN HEIGHT

NORMAL HOLSTEINS.

No. Cow	Birth Pounds	6 Months cm.	12 Months cm.	18 Months cm.	24 Months cm.
235	75				126.5
238	80		112.0	121.5	128.0
243	85	104.7	112.6	123.3	128.0
239	85		114.0	123.0	131.5
Av.	81.2	104.7	112.9	122.6	128.5
237	87				126.0
244	87	97.0	112.0	120.3	125.0
236	90				123.0
249	90	96.7	111.3	118.0	126.3
Av.	88.5	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
Av.	96.5	101.1	113.8	120.8	126.1

TABLE 23.

RELATION OF BIRTH WEIGHT TO GROWTH IN HEIGHT

NORMAL JERSEYS

No. Cow	Birth Pounds	6 Months Cm.	12 Months Cm.	18 Months Cm.	24 Months Cm.
91	35		105.0	113.3	119.8
96	40	96.0	111.2	120.3	123.5
61	50				119.5
102	50	89.5	103.5	110.0	114.1
Av.	43.7	92.7	106.6	114.5	119.2
83	50				118.5
90	50		109.5	115.3	120.0
98	55	97.0	110.5	117.7	122.3
100	55	90.7	107.0	113.8	119.3
Av.	52.5	93.8	109.0	115.6	120.0
101	57	94.0	109.5	115.8	118.4
93	62		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	122.5
Av.	65.2	94.5	109.1	116.3	121.7

TABLE 24

RELATION OF BIRTH WEIGHT TO MATURE

HEIGHT AT WITHERS

Holsteins			Jerseys		
No. Cow	Birth Weight Pounds	Height Withers Mature Cm.	No. Cow	Birth Weight Pounds	Height Withers Mature Cm
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
Av.	68.3	131.8		39	124.6
			39	50	120.0
			13	50	123.4
			22	50	119.7
			50	52	128.1
227	80	132.9	58	55	125.0
221	85	140.9	8	55	124.3
222	90	130.6	14	55	119.0
223	90	134.4	64	56	131.0
Av.	86.2	134.7	Av.	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
Av.	103.8	136.8	Av.	63.2	127.1

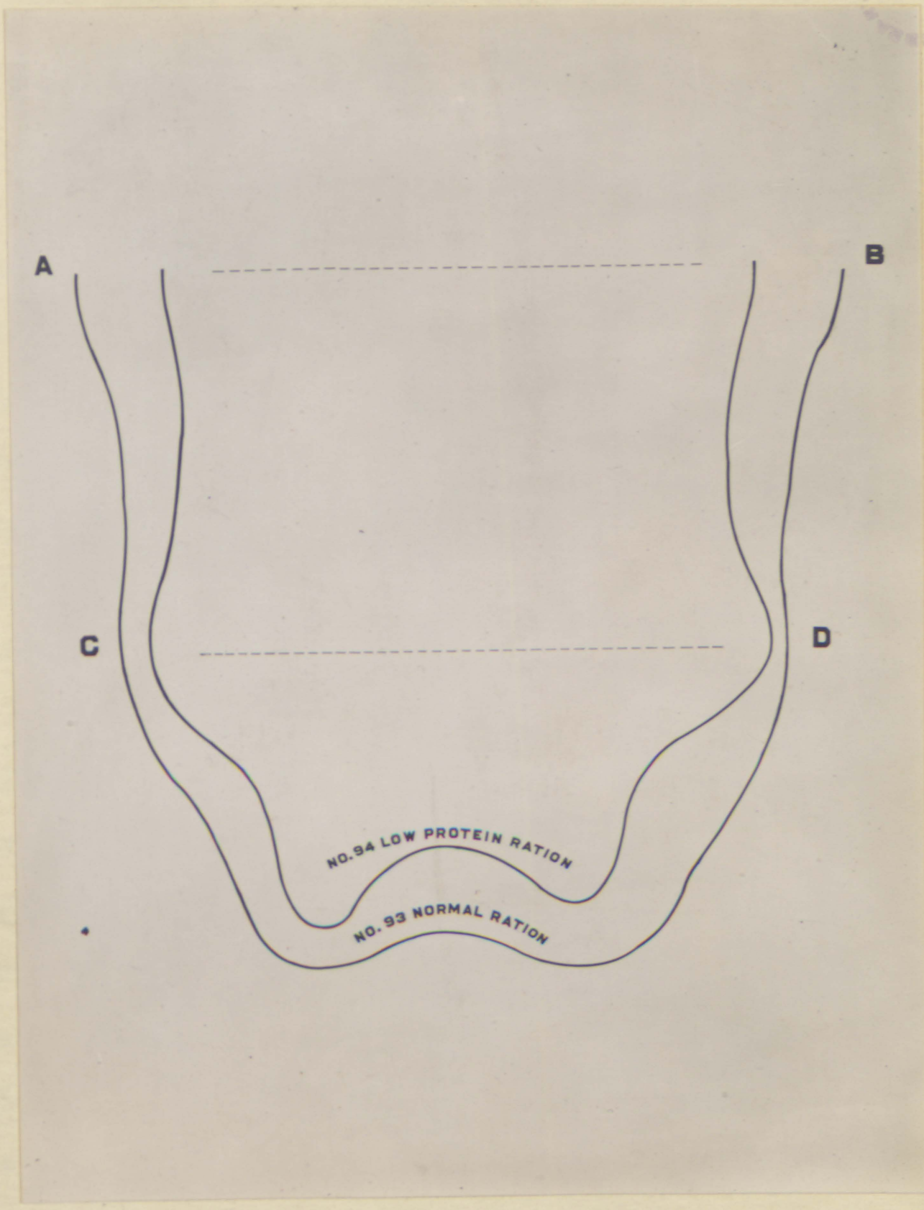
CONTOURS.

In order to show an example of the previously described abnormal shape of animals under adverse conditions, two Jerseys are compared in respect to their contours. Number 93 was born March 14, 1913, has been raised under normal conditions, and appears to be fairly typical of the breed. Number 94 was born February 7, 1913, but from birth has been kept on a ration of low protein. The contour line includes a plane of the posterior part of the animal, passing through the widest part of the hip-points and the widest point of the thurls. The width of the thurls of No. 94 is greater than the width at the hip-points -- a condition which is very unusual. The width of the thurls is 41.0 centimeters in No. 94 and 43.25 centimeters in No. 93 --- a difference of 2.25 centimeters. The width at the hip-points or hooks is 39.25 centimeters for No. 94 and 50.5 centimeters for No. 93. -- a difference of 11.25 centimeters. It will be noticed that in the case of No. 94 the thurls are 1.75 centimeters wider than the hip-points, while in No. 93 the hip-points are 7.25 centimeters wider than the thurls.

It is of interest that No. 94 became totally blind at the age of about eleven to twelve months. Not only is she abnormal in this respect, but her calf was born in a weak condition and was not only blind, but was without eyes.

This example is not cited as conclusive, but is added as a matter of interest. Conclusions cannot well be based on one animal, but it appears in this case that width-development cannot have been controlled by the mechanical pressure of the food, as has been suggested by Waters[92], because No. 94 at all times received an abundance of dry matter. The cause of this asymetric development is unknown. The contours of No. 93 and No. 94 may be seen in Plate XXIV.

PLATE XXIV.



The effect of the ration on the width at hip-points. Contours of No. 94 on a low protein and No. 93 on a normal ration.
AB a line between the hip-points.
CD a line between the thurls.
Width at hip-points of No. 94 -- 39.25 centimeters.
Width at hip-points of No. 93 -- 50.50 centimeters.
Width at thurls of No. 94 - - - 41.00 centimeters.
Width at thurls of No. 93 - - - 43.25 centimeters.

THE EFFECT OF PREGNANCY UPON THE INCREASE OF THE WIDTH AT THE HIP POINTS.

The excessive increase in the width at the hip-points at certain ages in bovines, as well as in other animals, has led to a great deal of speculation. Many theories have been advanced. Some have claimed that it is due to an abundance of food in the digestive tract at the time. This has been used as an explanation of the narrowness which occurs in an animal on light feed[92].

The idea that it might be due to pregnancy led to a compilation of data, the summary of which is given in Table 25. These data were arranged by Mr. L. S. Riford from animals selected so that their ages at the time of first calving, in the early- calving groups, approximately coincided. The corresponding ages of the late-calving group were then compared with them. The table needs little explanation. The results obtained were negative, indicating that pregnancy in this case was not responsible for the increase in the width at the hip-points. The cause of this excessive and prolonged development has not as yet been satisfactorily explained.

TABLE 25.

RELATION OF PREGNANCY TO WIDTH OF HIPS.

Jerseys		Holsteins	
Early Calving	Late Calving	Early Calving	Late Calving
36.7	35.1	41.8	40.2
38.0	36.4	43.6	41.1
39.1	37.2	44.2	42.1
39.8	38.0	44.1	43.2
40.6	39.8	44.9	44.0
41.0	41.1	46.1	44.8
42.3	42.3	47.0	45.5
43.0	42.8	47.7	46.4
* 43.5	43.7	48.1	47.2
43.6	44.5	48.1	48.0
43.6	45.2	47.8	48.2
44.0	45.8	48.1	48.6
44.0	46.4	48.5	48.9
44.6		48.6	
44.9		49.0	
45.1		49.4	
45.5		49.6	
46.0		50.1	
46.4		50.7	
46.7		51.2	

*The horizontal line indicates the time of calving for the "early calving" group.

CONCLUSIONS

1. A dairy heifer does not grow symmetrically yet, throughout the growing period of the animal, the percentage increments of the body-parts bear a fairly constant relation to one another.
2. The constancy of the relation of the different percentage increments indicates that, for animals not under extremely abnormal conditions, the height at withers can be used as a fairly accurate index of skeletal growth.
3. Weight alone is not a satisfactory index of the growth of an animal on account of the extreme fluctuations to which it is subject.
4. From the ages of one to twenty-seven months, normal Holsteins and Jerseys make almost identical gains in height at withers. Nearly two-thirds the difference between the height of Holsteins and Jerseys at maturity is present at the age of one month. These observations indicate that the greater height attained by the Holsteins may be accounted for by the greater initial height and by a more prolonged period of growth which is characteristic of the Holstein breed.

5. The weight of normal Holsteins increases much more rapidly than does the weight of normal Jerseys of the same age.
6. Skeletal growth, as measured by height at withers, is complete before weight has reached its maximum.
7. A heavy-fed animal tends to approach maturity earlier than a light-fed one. The difference in skeletal size between the groups on these two rations is greatest from about twelve to thirty months of age. This difference gradually diminishes, but probably never disappears.
8. The ration has a more immediate effect upon weight than upon skeletal growth. The tendency to recover the resulting difference in weight seems to be stronger than the tendency to recover the corresponding difference in the height at withers.
9. Early calving has a tendency to check skeletal growth as measured by height at withers. The corresponding stunting in weight is even greater at an early age, but has a stronger tendency to be recovered. This stunting is, in all probability, due to the strain of lactation, and indicates that the tendency to produce milk

is even stronger than the 'inherent tendency to grow".

10. The birth-weight of a calf seems to bear no direct relation to the rate of growth or the size of the animal at maturity.

11. Some factor other than pregnancy seems to be responsible for the large increase in the width at the hip-points.

ACKNOWLEDGMENT.

The writer wishes to express his appreciation to C. H. Eckles, Professor of Dairy Husbandry, University of Missouri, for his helpful suggestions in the preparation of this thesis.

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COLLEGE OF AGRICULTURE
AGRICULTURAL EXPERIMENT STATION
DEPARTMENT OF ANIMAL HUSBANDRY

May 22, 1916.

Dean Walter Miller,
Academic Hall.

Dear Dean Miller:

In accordance with your request of May 16th I have examined the dissertation submitted by W. W. Swett. I am pleased to say that I consider it quite satisfactory both as to subject matter and composition.

Very truly yours,

H. O. Allison

Associate Professor of Animal Husbandry

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