THE UNIVERSITY OF MINNESOTA

GRADUATE SCHOOL

Report

of

Committee on Thesis

The undersigned, acting as a Committee of the Graduate School, have read the accompanying thesis submitted by Otto G. Schaefer for the degree of Master of Science They approve it as a thesis meeting the requirements of the Graduate School of the University of Minnesota, and recommend that it be accepted in partial fulfillment of the requirements for the degree of Master of Science.

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August 2, 1920

THE UNIVERSITY OF MINNESOTA

GRADUATE SCHOOL

Report

of

Committee on Examination

This is to certify that we the undersigned, as a committee of the Graduate School, have given **Otto G. Schaefer** final oral examination for the degree of Master of Science. We recommend that the degree of Master of Science be conferred upon the candidate.

Minneapolis, Minnesota

August 2, 1920

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ENERGY REQUIREMENTS

FOR

THE NORMAL GROWTH OF DAIRY HEIFERS.

A Thesis Submitted to the

Faculty of the Graduate School of the

University of Minnesota

by

Otto G. Schaefer

In partial fulfillment of the requirements

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O U T L I N E .

Page

Introduction.. 1

The Problem of Growth... 3

General Considerations.................................. 3

Definition of...................................... 3

Measure of... 4

Nature of.. 5

Internal Secretions and Growth.......................... 8

General Discussion................................. 8

Pituitary Body..................................... 12

Adrenal Bodies..................................... 14

Thyroids and Parathyroids.......................... 15

Thymus... 17

Pdneal Body.. 18

Sexual Glands...................................... 19

Pancreas... 20

Nutrition and Growth.................................... 22

Requirements for a Complete Ration................. 22

Protein.. 24

Energy... 30

Mineral Matter..................................... 34

Vitamines.. 39

Other Factors...................................... 47

Page

Energy Requirements for Growth.................................. 49

Review and Discussion of Literature.................. 49

Feeding Standards for Growth of Dairy Heifers... 49

Energy Requirements for Maintenance and Growth.. 51

Experimental Work.................................... 54

Object of the Experiment........................ 54

Methods of Study................................ 55

Plan of the Trial............................... 55

Heifers Used.................................... 56

Rations Used.................................... 56

Methods of Feeding.............................. 57

Weighing and Measuring.......................... 58

Discussion of Data................................... 59

Group 1, Receiving Protein and Energy According to the Armsby Standard.................... 69

Group 2, Receiving Protein According to the Armsby Standard, Energy 15% Below......... 78

Comparison of the Two Groups.................... 79

Summary of Results.............................. 83

Relation of Breed to Gain in Weight............. 85

Relation of Age to Gain in Weight............... 87

Conclusions... 88

INTRODUCTION.

It is a well recognized fact that only a small part of the energy stored up in the crops of the farm is directly available for the use of man. Even in distinctly food crops, such as wheat, not more than one-third of the energy there-in is available for human nutrition, while the grasses and legumes, so important in all systems of agriculture are of no direct value as food for man. The essential function of the animal in a permanent system of agriculture is the conversion of as large a proportion as possible of these inedible products intó forms which are available for the human body. It has been proven that the dairy cow makes this conversion with the maximum efficiency, and that this product is our most complete and indispensible food.

If these crops are to be successfully converted into human food, the cow population must be maintained, both in number and efficiency. In the dairy herds in the United States alone, not less than nine million heifers are on hand at any one time. No less than four and one-half million must come to maturity each year to replace the cows which have outlived their usefulness.

The rapid increase in the percentage of urban population, and the consequent increased demand for food from the farm has brought about a marked increase in the value of land, livestock, and of all feeding stuffs. As a result of these conditions, the question of raising the cows to maintain the dairy herd is becoming more difficult and expensive from year to year.

Confronted with this situation, to be a successful breeder and grower of dairy cattle requires, an intimate knowledge of the fundamental scientific principles underlying the art of stock feeding and a readyness to take advantage of every aid which science and experience offer in order to make his business a financial success.

Scientific study of nutrition began on mature animals, and while the dairy cow has received her share of attention, the feeding of growing animals has not until recently been the subject of very extensive study. Considerable data have been collected dealing with the factors effecting growth and nutrition in general. However, such information as is available concerning the protein and energy requirements of growing cattle is either based upon a decidedly limited amount of data or is calculated from results obtained by a study of mature animals. This thesis reports data taken on one phase of the nutritional requirement of growing dairy heifers, that is the energy necessary for normal growth. A general discussion of the problem of growth with a review of the literature on the subject is included.

THE PROBLEM OF GROWTH.

General Considerations.

No work dealing with the feeding of immature animals would be complete without a discussion of growth,- its nature and the factors effecting it.

<u>Definition of Growth.</u>- A host of able investigators have studied growth, and definitions of the term "growth" are almost as numerous as are the men who have written on the subject. Although we find no two men defining the term alike, there is a general understanding of what is implied by the word in its ordinary sense.

Mendel[1] says there is no satisfactory definition of "growth" and comments upon the subject as follows, "One cannot penetrate into the literature of the subject without meeting with a bewildering confusion in the significance of the term. The most general definition of growth is 'increase in volume' or 'increase in size'(Hutley). It has been pointed out, however, that an increase in volume does not always serve as an index of organic growth; for the increase may merely be due to swelling. Sachs defined growth as an increase in volume accompanied by a change in form. No universally acceptable definition has been framed; nor is it likely that one can consider all of the manifold features of growth in a single category. What is needed today is less of theory and more of facts upon which to build a more substantial conception of growth and formulate its final characteristics in words."

Armsby[2] states, "Growth may be characterized briefly, as consisting in an increase of the structural elements of the body, chiefly by cell multiplication, resulting in a gain in size and weight."

According to Mumford,[3] during the period from the fertilization of the egg until the full development of the mature individual, the animal increases in volume and changes in form, and this increase and change in form is called growth. This definition is very similar to the one advanced by "Babcock and Clausen",[4] reading as follows, "In growth are included all those changes and cycles through which the individual passes in attaining the adult condition."

All growth,[5] whether of the cells, the tissues, or the organs, is the result of no more than three processes, viz., multiplication of cells, enlargement of cells, and deposition of intercellular substance, the first being most potent of all.

Measure of Growth. Inasmuch as growth involves a more or less continuous change, there is need of some criterion thereof - some suitable method of ascertaining and measuring it. This is by no means as readily accomplished as might appear at first glance. At present some experimentors use body weights, while others use stature and body proportions. Weight is not a complete indication of the growth of an animal, as it may be pronouncedly altered by deposition or removal of reserve materials such as glycogen and fat, as well as by the retention of water and other products. Aron[6] has pointed out that growth depends principally on the tendency to grow, posessed by the skeleton. Waters[7] has described conditions of adverse nutrition in young animals in which no change in body weight occurred during long periods of time. Nevertheless the animals grew from the standpoint of changes in stature and body proportions. Evidently, then, there are limitations to the dependence on weight measurements.

If it is assumed that skeletal measurements in addition to weights are essential in measuring growth, then the question at once arises which of the many possible measurements shall be used.

Eckles and Swett[12] after studying extensive data on the different methods of measuring growth state, "The first impression from a glance at these figures is that one measurement cannot be used to represent the general body growth and that surely, when an animal never doubles its height, when it more than doubles its circumference, and when it more than triples its width, the growth of the different parts of the is all out of proportion. A more complete study of the situation, however, shows that while one part of the body may double and another triple itself, the relation of the growth of one part to another is very nearly constant at all ages."

The general conclusion seems justified from these considerations that any one of the fundamental measurements of the body may be used with a fair degree of accuracy as an index of skeletal growth. Since the error in taking measurements which represent the height at withers seems to be as slight as any, and to be effected to a small extent as any by varying conditions of the animal, this measurement has been chosen as a standard to represent skeletal development.

Nature of Growth. When the parent cells unite at the time fertilization of the egg takes place, in some unknown manner a powerful force is set free which has been termed by some the "growth impulse", by others the "growth tendency" or "inherent tendency to grow". Babcock and Clausen[8] say"the development of the individual is a consequence of the elaboration of the hereditary material, it is the fulfillment of the possibilities wrapped up in the germ cell." Martin[9] states, "All cells during the early life possess the power of growth, or in terms of their chemical activities are able to assimilate faster than they dissimilate."

According to Minot,[10] "the impulse to grow is imparted with the union of the generative cells, and uterine life is characterized by rapid growth." He adds that in man the growth of the germ up to the time of birth represents an increase of over five million per cent; and in rabbits over 98 per cent ofthe growth impulse is lost before birth. He adds, "The loss in rate of growth is greatest in the young, least in old age, and that as we go back from old age towards youth, and then into the embryonic period, we find it an ever increasing power of growth, but that it is during the embryonic period that the loss of the power of growth is greatest."

Mendel[11] writes that quite aside from the question as to what initiates growth, the capacity to grow - the "Wachstumsfähigkeit", "Wachstumsmöglichkeit" as it has variously been termed - is commonly made a property of the cells of the organism. Whatever may be the ultimate cause of growth, the capacity to grow is currently associated with a youthful character of the cells involved. From this standpoint an embryonic condition of the cells is accordingly most favorable to growth. The individual has certain possibilities wrapped up in the germ cell, or growth impulse, which makes it possible to attain a certain size; or we may say 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. The maximum size cannot be attained unless both of these factors are given free scopes. The growth impulse is spent, and full size is not reached unless adequate food is present, and when once spent no amount or variety of feeds can revive it. On the other hand no amount of food can force the animal to grow beyond its pre-determined size.

In general the dominant impression seems to be that the capacity to grow belongs essentially to the earlier periods of the life cycle; or at any rate it is believed to be more characteristic of that time. Accordingly it would appear that this unique property of living substance is sooner or later lost, at least in as far as it pertains to the higher animal forms.

Thus it would appear that growth is the result of an internal source and receives an additional impetus from an external source. It seems to be the general opinion that hormones or secretions of ductless glands are responsible for the growth impulse, or internal source, and it is a known fact that food is the external source.

Since the animal is directly dependent upon these two sources for its growth and development, that is the internal and external stimuli, it seems advisable, at this point, to discuss separately each of these factors.

Internal Secretions and Growth.

It seems to be the general opinion that special internal secretions are responsible for the growth stimulation. Killicott[14] says, "It seems likely that in organisms in general, the normal growth of each tissue or of each organ is controlled separately by a specific internal secretion. These substances may regulate growth either thru inhibition or acceleration, and the effect produced may be due either to the presence or the withdrawel of specific substances." This is substantiated by Martin[15] who states, "in growth and development chemical coordination is secured by specific internal secretions which govern those body activities that are either not readily susceptible to nervous control or in which the best results are secured by supplementing nervous control by chemical."

These secretions[16] are special substances secreted by glandular tissue which, instead of being carried off to the exterior by a duct, are eliminated in the blood or lymph. They[17] are formed in organs whose sole function, so far as is known, is their production. The organs[18] which elaborate these secretions are usually referred to as the glands of internal secretion, or ductless glands, since they pour their secretions into the blood stream and not by duct to the surface; but Schäfer[19] uses the name "endocrine organs"; while Mathews[20] calls them "crypterrhetic organs."

The conception that these ductless glands give rise to chemical products which are entering the circulation, and influence the activity of one or more other organs, thereby effecting the growth and development of the animal, has recently found a fruitful application in the study of the digestive secretions. To such substances that are derived from one organ and influence another after

after their passage into the blood stream, Starling[21] in the year 1902 gave the name of chemical messenger or "hormone." This term has found wide use in physiological literature and is generally accepted; however, some writers have felt tht a more characteristic name should be adopted. Schäfer[22] says, "Since the most characteristic feature of the action of these substances is the resemblance to the action of drugs, I propose to employ for these specific substances the general term of autocoid substances, or simply autocoids. I would accordingly define an autocoid as a specific organic substance formed by the cells of one organ, and passed from them into the circulatory fluid to produce effects upon other organs similar to those produced by drugs."

The evidence[23] of the existence of hormones has been furnished in three ways, (1) substances physiologically active were demonstrated in the blood or lymph leaving the gland in question; such direct and conclusive proof has been furnished as yet only for one gland, the adrenal. (2) Excision of the gland produced characteristic changes in the vital processes which could be prevented by implantation of the gland in question or by the administration of preparation of the same gland. Evidence of this character was brought out regading the hormones of the pancreas, thyroid, parathyroid, hypophysis, adrenals and sex glands. (3) Pathologic entities of supposed hyperfunction of some glands could be initiated artificially by administration of overdoses of the substance of the gland in question

The apreciation of the presence of glands of internal secretion was not a direct and conclusive discovery made at any one time, but was the result of various theories held from time to time, which finally led up to the present conception of endocrinology.

For hundreds[23] of years the medical world assumed a mutual influence of the various organs of the human body upon each other; and as early as the 17th century it was believed that every organ of the human body had a certain influence upon the juice-mixture of the whole body.

In 1628 Harvey[23] discovered the circulation of the blood, which was then assumed as the means of communicating between the various organs. Then came Thraphile de Borden, claiming in 1775 that every organ creates specific bodies necessary for the integrity of the whole organism, which enter the blood either by lymphatic or nervous channels. He then explained symptons accompanying castration, puberty, etc.

The first,[23] however, who drew a line between "secretion" and "excretion" of the various glands was Johannes Mueller in 1830. Among the secretory glands he classes the spleen, thyroid, adrenals, thymus and the placenta.

The first[23] to prove experimentally the influence exerted by the internal secretion upon the blood was A.A. Berthold (1849), who transplanted the testicles of young cockerals and noted that these cockerals, in spite of being castrated, remained normal cocks as far as vocal powers, sexual instinct, desire of combat, comb growth, etc. were concerned.

Shortly[23] after this came Brown-Sequard, who taught at the medical faculty in Paris in 1869, that all glands, whether endowed with execretory ducts or not, constituted necessary and useful substances to the blood, which when lacking, produced pathologic symptons. This same man twenty years later set the birth date for the present knowledge of the therapeutics of the internal secretions, when at the age of 72 years he reported on some experiment made on own body with subcutaneous injections of the testicular juice; he claimed to have observed on himself, after such treatment a surprising increase of vigor, cerebral function, appetite and intestinal activity.

The work done since 1889 has demonstrated fully that some, perhaps all of the ductless glands play a role of the very greatest importance in general nutrition. They yield internal secretions of one kind or another, and modern investigators have demonstrated that there is a complicated interrelation among the secretions as regards their action on body metabolism.

Among the internally secreting organs are classed the adrenals, hypophysis or pituitary body, thyroids and parathyroids, thymus, pineal body, reproductive glands and the pancreas. These glands may be divided into two groups, according to the action of their hormones. There[24] is (1) an accelration group, and (2) an inhibitory group. The thyroid,pituitary, and superarenals belong to the former group, since it has been shown that all three increase protein metabolism, that the adrenals cause mobilization of the carbohydrates, and that the thymus and thyroid cause increased fat absorption. To the inhibitory group belong the pancreas and parathyroids, since both retard protein exchange and both restrain the mobilization of carbohydrates, in each case the pancreas being the more powerful.

It cannot be said with absolute certainty just which of these ductless glands influence the growth of the organism because of their interdependence and reciprocal influences. Mathews[25] says that the hypophysis, thyroids, sexual glands, adrenals and thymus are a closely related series of organs which mutually influence each other's growth. The thyroid and hypophysis stimulate chromaffine tissue, the latter inhibits the pancreas, ovaries and parathyroids; the latter inhibit, or are inhibited by, the thyroids, and hypophysis. He adds, "The body[26] is an organic whole and these so-called cryptorrhetic organs, organs of internal secretion, are not unique, but the bones, muscles, skin, brain, and every part of the body are furnishing internal secretions necessary to the development and proper functioning of all the other organs of the body.

<u>Pituitary Body (Hypophysis).</u> This body[27] lies at the base of the brain, and in humans is about[28] the size of a pea, weighing about one half gram, and is in direct[29] connection with the brain.

Livingston[29] states, "There is no constant sex difference in the weight of the hypophysis; neither sex show a constant hypertrophy of the hypophysis after castration or spaying."

Howell,[30] as well as Bainsbridge and Menzie, state that when extracts of the posterior lobe are injected into the circulation several distinct results have been observed to follow, extracts of the anterior lobe when injected yield no immediate results. This is contradictory to the results secured by Robertson[31] who has named the growth controlling principle of the anterior lobe of the pituitory body tethelin. He found that the effect of tethelin upon the growth of white mice resemble in every particular the effect of the administration of the whole anterior lobe.

The same author[32] observed further results of the administration of tethelin and concluded, "factors which favor the growth of one particular type of tissue or the growth of the whole animal at a particular age may actually exert the reverse upon another tissue or at another stage in the growth of the animal concerned." Roselind and Wulzen[33] hold that the animal must be very young if growth is to be accelerated by a diet of pituitary.

According to Mathews[34] the removal of pituitary body shows a marked influence on the animal. He states, "In the absence of the anterior lobe in young animals growth is checked, an increase of fatty deposit occurs and a persistent infantilism, such as infantile sexual organs, a long retention of puppy hair and milk teeth; lack brain development and intelligence; a lowered body temperature; and a lowered nitrogen decomposition of the tissues. In adults there is no marked change, except an increase in fat; a lowering of temperature, and lowered nitrogen output."

The removal of the posterior lobe does not effect the well-being of the animal to any known marked extent. Mathews[34] quotes "No disturbance of the growth takes place when it alone is taken out." Goestach[35] summarizes the experimental work as follows, "Pituitary extract (anterior lobe), when fed to young rats, has a stimulating effect upon growth of the animal and upon the sexual development and activity. Posterior lobe extract, when thus given, has a retarding effect."

It seems evident from the foregoing experimental work and clinical observations that the pituitary body is essential in some way to normal body-metabolisms, and moreover that the anterior and posterior lobes exercise different functions. It appears that the anterior lobe furnishes a secretion that stimulates the growth of the skeleton and possibly the connective tissues in general, and in addition exercises some deeper influence on metabolism of an unknown but essential nature. The posterior lobe, on the contrary, furnishes one or several hormones that have a stimulating effect upon several processes, - the tone of the plain muscle, the secretory activity of several glands, and the process of glycogenolysis. In addition, this portion of the gland shares with others of the ductless glands (thymus cortex of the adrenal glands) a regulating influence upon the normal development of the reproductive organs.

Adrenal Bodies. The adrenal bodies (suprarenal capsules) are two small glandular organs lying like caps on the upper poles of kidneys, and according to Vincent[37] "what we call the adrenal body represents the anatomical association of two elements, the adrenal body proper or cortex, and the medulla.

It was first[38] shown by Brown Sequard that the removal of these bodies is followed rapidly by death. In addition he showed thatthe removal of but one organ seems to effect animals so slightly that they appear to suffer no inconvenience, they continue to live month after month, quite well and active, until the experimentor removes the second adrenal when death occurs within thirty six hours.

The main[38] function of the adrenals is to supply an internal secretion which absorbs the oxygen of the air to carry it to the tissues, and as a result of this fact:- pulmonary respiration and tissue respiration. It has further been noticed that an injection of this substance causes a pronounced slowing of the heart-beat together with a rise of temperature.

Hopkins[39] observed that an injection of adrenin provokes an increased metabolism of protein in the fasting animal. Zoeper and Verpy[40] found that an intramuscular injection of one milligram of adrenalin in human subjects caused an increase in secretion of H.C.L. in the stomach as well as augmentation and acceleration of the contractions in the digestive tract.

Vincent[41] states, "Feeding young animals with adrenal gland substance seems to stimulate the growth of the testis. Other observers have called attention to the fact that the cortex has some relation to the activity of the sexual glands.

Experimenatal work has disclosed little knowledge and the work does not warrant conclusions, however, Sa Jous[42] summarizes one of his works as follows, "The symptons of certain diseases, or that follow extirpation of the adrenals, strikingly emphasize a connection between these organs on the one hand and the heart and the respiratory process on the other.

Thyroids and Parathyroids. For a long time[44] the thyroid and parathyroids were supposed to have similar functions. However, recent experimental work on these organs make it necessary, now, to distinguish between them.

The thyroid gland[45] is a small highly vascular, ductless gland, lying in the neck close to the larynx, and is composed of three parts, two lobes lying close to the larynx, one on each side and a little to the front of the trachea, and an isthmus connecting the two.

The parathyroids[46] are according to most authors quite different structures. Four of these bodies are usually described, two within the thyroid called the internal parathyroids, and two without, or external parathyroids.

Numerous[46] experimentors have shown that when the parathyroids alone are removed the animal dies quickly with acute symptoms, muscular convulsions (tetany) etc. When the thyroids alone are removed the animal may survive for a long period, but developes a condition of malnutrition.

The experimental[47] evidence in the case of the parathyroids tends to support the view that their function consists in neutralizingin some way toxic substances found elsewhere in the body, and that, therefore, after the removal of these glands death occurs from the accumulation of such toxic bodies in the blood and tissues.

Our knowledge concerning the thyroid is somewhat more complete, however, not all of the details of its action are known. Howell[49] states, "No adequate explanation has been furnished of the influence exercised by the thyroid on the nutrition of the body. It is usually assumed that the thyroid cells form an internal secretion containing a specific hormone which acts as a chemical stimulus to other tissues, causing a hastening of their metabolism.

Tescohier[50] states if the gland fails to develop or atrophies or developes insufficiently in embryonic life, a cretin is the result. Growth is retarded and a dwarf is produced, with low intelligence, coarse hair, and thick dry skin. It is[48] then that arrested mental and physical development is a result of thyroid insufficiency.

On the other hand,[51] if the organ is too active, exophthalmic goitre, so called from the protuberance of the eyes which commonly occurs, or Basedow's disease, results. In this case the symptoms are generally the reverse of those in diminished function. The heart is very fast and often irregular; instead of a low temperature, the temperature is high, and there is a great nervous irritability in place of nervous sluggishness.

Schafer states,[52] "The important influence exerted by the thyroid secretion on nutrition generally, no doubt, is responsible for the fact that hardly any organ in the body remains uneffected as a result of its complete removal or atrophy. But the secreting organs with which it may be regarded as being specifically associated are few."

Nickerson[53] examined a bull dog calf, pug nose, short body and very short legs, - weight 30½ pounds, and in an examination of the endocrine glands it was discovered that the thymus was present and normal; two large massēs of tissue in the position of the thyroid lobes were histologically typical thymus tissues and no thyroid tissue was found.

The thyroid[54] is peculiar among all the glands of the body because it normally contains iodine. No other tissue is known to contain iodine except possibly the pituitary, and here the evidence is doubtful. Both Fenger[55] and Mills[56] state that there is a seasonal variation in the iodine content of the thyroid, and Fenger[55] summarizes the subject by saying, "A distinct seasonal variation exists in the iodine content of the thyroid gland from cattle, hogs, and sheep. The temperature which is the most important of all in producing these fluctuations. Mills states further, "High external temperature causes a diminished activity of the thyroid, and low temperature, on the contrary, increases the thyroid activity and also seems to cause a faster rate of growth.

Mathews[51] sums up the subject by saying, "It is clear that this small organ is enormously important in the proper development of bone, teeth, skull, brain and skin of the body; that its absence is attended by retrogressive changes in these tissues and organs; and that when it overfunctions it stimulates metabolism and nervous activity."

Thymus. The thymus is a glandular organ located in the anterior, superior dividing membrane or wall of the thoracic cavity. It is essentially an organ of early life, being well developed at birth. It retains[57] its size and presumably its full activity until the period of puberty. Thenceforward it undergoes a gradual atrophy, but apparently throughout life some remnants of the gland tissue persist embodied in fat.

The physiology[57] of the thymus gland is very obscure, in fact, nothing that is definite can be said about its functions. By many observers[58] the glands have been brought into relation with the growth of the bones, and calcium excretion, but this evidence is contradictory. It is now recognized that the action of this gland may be a complicating factor in goiter. Gudernatsch[59] reports that the thymus has the power to stimulate growth in tadpoles, but lacks the power to excite differentation. Hewer[60] after experimentation decided, "that beyond inconstant and slight variation, no definite general growth changes are brought about in rate by thymus feeding, apart from alteration of sexual activity. With moderate doses of thymus sexual maturity is delayed. Feeding the parents with thymus caused marked delayed sexual maturity in the offspring both male and female. With larger doses of thymus in the female no histological alteration of structure was observable, while in the male the testis is structurally affected; in the young animal in the direction of retardation of the development; in the mature rat in the direction of degeneration. This degneration is confined to the testis. The thymus gland itself does not appear to be influenced by thymus feeding.

<u>The Pineal Body.</u> The pineal body or gland is a rudimentory organ in the brain corresponding in a general way on the upper surface of the hypophysis on the lower. The function of this organ is still unknown, but it appears to be closely related to the sexual organs. Intravenous[61] injections of extracts of this gland seem to cause a distinct fall in blood pressure, indicating the presence of a depressor substance. Fenger[63] in his work with the pineal body noted that, especially during pregnancy, the gland contains considerable amounts of phosphatids in excess of ordinary muscle tissue, indicating that the phosphatids play some part in the internal chemistry of this gland. He states "that the pineal body contains

active principles of physiological significance." McCord[64] fed pineal gland to young chicks and guinea pigs and accelerated their development.

The Sexual Glands. That the ovaries and the testis have a very marked effect on the growth and metabolism of the body has long been known. Castration[61] has long been practiced with the purpose of modifying body form and temperament. Most of the recent work has indicated quite clearly that the reproductive glands control the development of the sexual characteristics, not by way of a reflex nervous effect, but by way of the blood; that is to say, through an internal secretion. This work, however, tends to show that the internal secretion is formed not by the spermatoza or the spermatogenia, but rather by the so-called interstitial cells which lie outside of the seminal tubules. When a young animal is castrated completely the secondary sexual characteristics and sexual appetite do not develop. If, however, the vas deferens is ligated, the sexual elements may disappear, while the interstitial cells remain and increase in number.

Many experiments[65] and observations indicate that the internal secretions of the ovaries and testis are important, not only as regards so-called secondary sexual characters, but also in regard to body metabolism in general. Mathews states, "The productive organs give off either from the germ or interstitial cells substances which, circulating in the blood, change the growth of the horns and bones of cattle, the development of the hair and mammary glands, and genitals in human beings and profoundly modify the general physiological properties." Iscoresco[66] indicates that the lipoid extracted from the ovary, when hypodermically injected in rabbits, had a regulating and accelerating action on the growth of young animals; and a similar use of a lipoid extracted from the testicle accelerated growth in young animals and caused an increase in weight in full grown animals.

Pancreas. It is a known fact that the pancreas is responsible for the production of some substance which exerts a marked influence on carbohydrate metabolism. The exact nature of the secretion is apparently unknown. According to Howell[65] the internal secretions regulate in some way the sugar out put from the liver and other organs. In the absence of this secretion an over supply of sugar is thrown off into the body which interferes with proper metabolism. This, however, is more closely connected with the nutritional phase than growth, and will be taken up later.

Bayliss and Starling[67] in their work on the mechanism of pancreatic secretions conclude, "The secretion of the pancreatic juice is normally evoked by the entrance of acid chyme into the duodenum and is proportional to the amount of acid entering. The contact of the acid with the epithelial cells of the duodenum cause in them the production of a body secretion which is absorbed from the cells by the blood current and is carried to the pancreas where it acts as a specific stimulus to the pancreatic cells, exciting a secretion of pancreatic juice proportional to the amount of secreation present."

Thus it seems there are two internal secretions which are closely connected with the pancreas. The first is produced by the pancreas and controls the sugar output while the second is produced in the duodenum and controls the pancreatic juice.

The ductless glands are so closely related that it can not be said definitely which is the most essential in growth. Mathews[68] says,"It is clear that the ductless glands are a closely related series of organs which mutually influence each others growth. The thyroid and hypophysis stimulate the chromaffine tissue, the latter inhibits the pancreas, ovaries, and parathyroids." He adds, "These cytorrhetic organs, organs of internal secretion, are not unique, but the bones, muscles, skin, brain and every part of the body are furnishing internal secretions necessary to the development and proper functioning of all the other organs of the body." Sojous[69] believes that with an understanding of the ductless glands we may materially prolong life.

Nutrition and Growth.

In addition to the internal factors already discussed in connection with their relation to the growth and development of the animal, there remains the external influence, or primarily the nutritional factor. Our knowledge of nutrition has progressed hand in hand with the development of the science of chemistry and has given us an understanding of the nature of the food-stuffs and changes which take place in digestion, as well as some of the secrets of the metabolic processes which take place within the tissue of the body. While we have witnessed great progress in the study of nutrition in the past, further study will doubtless reveal many other important facts.

Requirements for a Complete Ration. Although[70] animals have been fed for many hundreds of years, it was not until 1859 that the first feeding standard for farm animals was proposed. This standard by Grouren was based on the crude protein, carbohydrates, and fat in feeding stuffs. This, however, was imperfect as it was based on the total instead of the digestible nutrients. In 1864 Wolff presented the first feeding standard based on the digestible nutirents contained in feeds, setting forth the amounts of digestible crude protein, carbohydrates and fat required daily by the different classes of farm animals.Various other standards are based upon this same fundamental conception. Until recently standards of this type were considered to fill the demands of a complete diet. Then came recognition of the fact that the mineral constituents of the diet were of importance.[71] However, progress was not halted here, for modern research in nutrition demonstrated that there is a great difference in the biological value of the proteins from different sources. This discovery induced many investigators to work with the isolated proteins from different sources, and feed them in connection with purified food substances. This brought to the notice of dieticians other heretofore unknown dietary essentials which were first made conspicuous by their absence in supposedly complete diets. These studies clearly suggested that there was required in the diet something other than protein, carbohydrates, fats and inorganic salts.

Then came the question of the requirements of the growing animal as compared to the adult. This is summed up by Mendel[72] as follows: "Aside from its energy aspects, the food requirement during growth is peculiar in that the intake of certain groups of nutrients, such as the proteins and inorganic salts, must exceed the demand for wear and tear, so that some excess will be available for the formation or completion of new cells and the elaboration of the tissues that especially develop in the period of growth. For the most part the materials included in the above requirement are merely those which are demanded in the usual maintenance of the grown adult, though perhaps in smaller proportions. It is not improbable, however, that the food needs of the growing organisms may in part be specific and peculiar, calling not only for a little more lime or iron or protein than the non-growing individual requires, but for special substances in addition."

It is now a fully recognized fact that in order to secure normal growth and functioning of the animal, we must furnish a complete ration. This ration must contain protein of suitable quality, a source of energy in the form of protein, carbohydrates, and fats, and both the fat soluble and water soluble vitamines.

Since these factors in the food supply are so essential to the proper growth and development of the animal it is advisable to discuss them separately.

Protein. Proteins have long been known to be one of the essential ingredients of the food of man as well as animals. For years the protein of feeding-stuffs has been treated as if it were a single chemical substance and assumed to have substantially equal nutritive values. The more recent investigations into the chemistry and physiology of the proteins, however, have resulted in an entire change in the point of view, and now[73] feeding experiments have fully established that there are great variations in the biological values of protein from various sources, which depend upon the proportions of the amino-acids they yield on digestion.

Since growth involves the construction of new tissues, and as protein plays such an important part in this process, it is apparent that the amino-acid content of each protein should be taken into consideration. Osborne and Mendel comment on this as follows:[74] "The current view of the construction of new tissue involves the synthesis of new protein as an essential feature. Growth will be limited, therefore, by any factor which prevents this synthesis. The lack of any component amino-acid which cannot be manufactured directly in suitable amounts in the body represents such a limiting factor."

In the process of protein digestion, the animal and vegetable proteins are broken up into their component parts, the amino-acids, and it is in this form that they find their entrance into the blood. Eighteen of these amino-acids have so far been isolated and identified. They are the primitive building stones of which the protein material of the body is to be constructed. Thus it can readily be seen that the quality of the protein is just as essential as the quantity, and the most efficient and economical protein supply can only be furnished after its amino-acid content is known.

The various proteins [76] differ in the amounts of the different amino-acids which they yield on hydrolysis. While it is not yet possible to determine many of the amino-acids quantitatively, yet it is possible for some of them, and approximations may be made for some others as follows:-

Per Cent of Amino-Acids Isolated from Various Proteins

Amino-Acid	Gliadin Rye	Gliadin Wheat	Herdein Barley	Zein Maize	Legumin Vetch	Legumin Cow Pea
Glycocoll	0.13	0.02	0.00	0.00	0.39	0.38
Alanine	1.33	2.00	0.43	9.78	1.15	2.08
Valine	?	0.21	0.13	1.88	1.36	?
Lencine	6.30	5.61	5.67	19.55	8.80	8.00
Proline	9.82	7.06	13.73	9.04	4.04	3.22
Phenylalanine	2.70	2.35	6.55	2.87	3.75	0.0
Aspartic Acid	0.25	0.58	Not found	1.71	3.21	5.30
Glutamic Acid	37.8	42.98	43.19	26.17	18.30	16.97
Serine	0.06	0.13	?	1.02	?	0.53
Cystine	?	0.45	?	?	?	?
Tyrosine	1.19	1.20	1.67	3.55	2.42	1.55
Arginine	2.22	3.16	2.16	1.55	11.06	11.71
Histidine	0.39	0.61	1.28	0.43	2.94	1.69
Lysine	0.00	0.00	0.00	0.00	3.99	4.98
Tryptophane	Present	Present	Present	0.82	Present	Present

From this table one can readily see that the mentioned proteins all contain practically the same amino-acids, but in different amounts. It is clear[77] that in general the various proteins are made up of the same units, and it undoubtedly follows that the individual protein characteristics are bestowed by the relative proportions of the units, or by their absence.

Qualitative and quantitative examinations have been completed for many of the proteins, however, our knowledge of the amino-acid content of our ordinary feeding-stuffs is very meager. Work is under way by various investigators, including Nallau,[78] Grindley, Joseph, and Slater, however, the work is tedious and the knowledge collected to date rather limited.

The most extensive investigations relative to the nutritive value of these amino-acids to laboratory animals have been conducted by Osborne and Mendel, McCollum and associates, and others, and their results contain much valuable and enlightening information. Their method consists essentially in the feeding of isolated and purified proteins, and amino-acids from various sources, with basal rations which are otherwise adequate for maintenance or growth and of known composition. By this method it has been demonstrated that different proteins have different values in nutrition, and these differences have been clearly shown to be due to the variations in the amino-acid content.

Some[79] of the amino-acids which the body tissue need for repair or growth may be made in the body from other amino-acids, glycin, for example, but others apparently must be furnished in the properties of the food, and if they are lacking, tissue construction is not possible. Therefore, to make intelligent use of these substances, it becomes increasingly important to know which of these building stones are necessary for growth, and which must be furnished by the food supply.

The bulk of the evidence at hand goes to prove that lysine[80] and cystine[81] are indispensible for normal growth. Tryptophane[82 & 74] on the other hand has an important bearing on growth and is essential even for the maintenance of full grown animals. Other investigators[82] have discovered that tyrosine has some bearing on maintenance, but not on growth. Of these Howell says,[83] "Tryptophane, lysine, and probably tyrosine, cannot be formed in the body, but have to be supplied from without in the protein food."

In dealing with the part that lysine plays in growth, Osborne and Mendel state, "Lysine is indispensible for the function of growth. No amount of energy or protein, however abundant, has induced growth of our animals in the absence of lysine. The animal organism apparently cannot synthesize lysine, which is evidently not essential for maintenance in the sense of preservation of body weight, though it is, of course, impossible to say that when this amino-acid is missing all functions are normally carried out. It is obvious that the possibility of growth must be limited, among other things, by the amount of lysine available."

In feeding young chicks on grain mixtures of high and low lysine content, Bucker,[84] Nallau, and Kastle observed normal growth on the high lysine content mixtures, and stunted growth on low lysine content. This work has been confirmed by Osborne and Mendel[85] in trials with diets of high and low lysine content.

Osborne[80] and Mendel give the lysine content of proteins from various sources as follows:

Lactalbumin	8.10%
Halibut muscle	7.45%
Ox muscle	7.59%
Casein (cow's milk)	7.61%
Vitellin, egg-yolk	4.81%
Crystallized albumin (hen's egg)	3.76%
Legumin (pea)	4.98%
Pascolin (kidney bean)	4.58%
Glutelin (maize)	2.93%
Glutelin (wheat)	1.92%
Edestin (hemp seed)	1.65%
Amandin (almond)	0.72%
Gliadin (wheat)	0.16%
Hordein (barley)	0.00%
Zein (maize)	0.00%

The same[86] author in studying the comparative nutritive value of certain proteins in growth, observed that the addition of isolated cystine to the food at once rendered the ration decidedly more adequate for growth. Their results have been substantiated by Johns[81] and Finks who found that bean meal when fed alone was inadequate, but when cystine was added normal growth was secured. After an extensive review of the literature and further experimentation these authors state, "Cystine has been shown to be essential for normal growth."

Willcock[87] and Hopkins observed that the addition of tryptophane to a deficient protein dietary did not enable it to support growth of young mice, but greatly prolonged the survival of the animals. This was confirmed by Abderhalden.[88] Tyrosine has no such effect. They suggest that tryptophane is directly utilized as the normal precussor of some specific hormone or other substance essential to the processes of the body.

Work is under way dealing with the nutfitive value of some of the other amino-acids, and we find a report from Ceiling[89] of work on Arginine and histidine in which he claims these two acids seem to be interchangeable in nutrition. Therefore the absence of either one does not effect the well-being of the animal, as does the absence of some of the other acids.

Having collected some data on the quantity of the amino-acids in feeds and the effect of their absence or presence on the growth of the animal, some of the foremost investigators[90] held the view that that protein in our more common feeds, as the maize kernel, contains all the amino-acids essential for growth, but that the proportion of some of them are such that they are not utilized to a high degree as the only source of protein. In making good this deficiency of the maize kernel, Osborne and Mendel state, "The efficiency of supplements presumably depends essentially upon this relative content of lysine and tryptophane. It is evident that the small additions of more efficient proteins actually supplement the corn gluten instead of themselves furnishing all of the protein used for growth, because equivalent amounts of these proteins alone in a similar ration are incapable of inducting a comparable degree of growth. Small amounts of a superior protein are often just as efficient for growth as larger amounts of a less adequate protein." In either case enough must be supplied to correct the deficiency of the required amino-acid.

A so-called incomplete protein, i.e. one which when fed alone is quite inadequate to meet the requirements of protein metabolism, may nevertheless contribute towards these requirements to an important degree and may even play a prominent part in promoting growth as was strikingly demonstrated by Osborne[92] and Mendel in experiments in which they added zein to a ration containing a small percentage of lactalbumin. Here the addition of zein to the ration more than doubled the rate of growth. More recently McCollum,[93] Simonds, and Pitz feeding rats on rations composed of a single grain with supplementary additions, found that gelatin supplements wheat protein excellently, though it apparently does not appreciably improve the proteins of maize or oats.

In view of such evidence it is important to guard against the erroneous impression that incomplete proteins are useless for growth. The growing animal may use such proteins to extremely good advantage, but the "incomplete" protein must not be permitted to displace the "complete" protein to too great an extent if the young animal is to grow and develop at a fully normal rate.

Energy. The energy necessary for the ativity of the animal body must be supplied by the food it consumes. It[94] is generally recognized that the carbohydrates, fats, and protein all supply energy. Howell[95] states, "tha the mineral elements are of no importance from this standpoint," and Armsby[96] shows that the protein is a carrier of energy, however, the protein ingredients of the feed are first called upon to furnish structural material, and any excess may yield energy. This lessens the value of this ingredient as a source of energy. Thus the two primary sources of energy are the carbohydrates and fats.

Howell states, "The general value of the carbohydrate food to the organism may be summarized as follows:

(1) It furnishes a source of energy for the needs of the tissue cells and particularly for muscular work.

(2) The oxidation of the sugar furnishes an important part of the constant supply that is needed by the body.

(3) The oxidation of the sugar protects the protein of the body.

(4) Any excess of carbohydrates, taken as food beyond the power of the tissue to store as glycogen, may be synthesized to form fat."

Mendel[98] in commenting on the value of carbohydrates in the food states, "Without carbohydrates in the diet the nutritive function of a growing individual is menaced quite as readily as it is during adult life. Metabolism exhibits pathologic manifestations in the lack of carbohydrates."

The general functions of fats are summarized by Howell as follows:

"(1) It may be oxidized with the formation of heat energy to maintain the body temperature.

(2) It may be stored in the tissue as part of the body fat, and at a time of low food intake be converted into energy to serve the body.

(3) It may be synthesized with other substances to form more complex constituents of the body."

Fats, as the carbohydrates, are all practically equal in value as sources of energy, meaning that a certain amount of fat from different sources will furnish approximately the same number of therms of energy. However, Mendel and Osborne,[100] and other investigators in studying the records of growth on diets containing butter-fat and beef-fat, respectively, have gained the impression that butter-fat is more effective in supporting growth than equivalent quantities of beef-fat. This is not explained on an energy basis, but the fact that certain fats carry the "accessory substances A", while others do not. A separate discussion of this property appears later.

From the general functions of carbohydrates and fats one can readily see that the ultimate and primary function of these nutrients is the liberation of energy. It[101] would be anticipated, therefore, that the various digestible nutrients might mutually replace each other, and numerous experiments have shown that such is indeed the case. This is in accord with the work of Sherman who states, "The body is not restricted to the use of any one food-stuff for the support of any one kind of work, but on the contrary has very great power to convert one nutrient into or use it in place of another. The carbohydrates, fats, and proteins stand in such close mutual relations in their service to the body that for many purposes we may properly consider the food as a whole with reference to the total nutritive requirement, and express its value in therms of energy."

However, it is not the gross amount of energyontained in a feed which determines its value, but the amount which it is possible to get out of it and convert into other forms. Much of the gross energy of the feed escapes from the grasp of the body, some of it going into the manure heap, some escaping in the gases given off, and some being finally expended simply in warming the surroundings of the animal. The remainder constitutes the "net energy" or that which can be utilized to run the body machine.

Energy[104] is necessary for growth first, to supply the heat necessary to keep the temperature of the body high enough to permit the chemical process to occur with sufficient speed and keep the protoplasm in the necessary condition of viscosity; second, to furnish the energy which is transformed in doing external and internal work, and third, to furnish the energy used in the synthesis of specific materials in the body.

A diet adequate in every respect except the energy requirement, when fed to a young growing animal, results in an energy deficit. Waters[105] has described experiments which appear to have been of this character. He reports numerous cases of young cattle on restricted amounts of food of suitable kinds, the restriction being such as to materially retard the increase in weight as compared with that of a full fed animal of the same age, when it should have been growing rapidly. In such cases of insufficiency of the total energy intake the skeleton continues to grow in height at least, while adipose tissue steadily disappears, and the muscles become more or less depleted. In young animals subjected to this type of under-nourishment the skeleton grows in height to a much greater extent than in width.

A similar experiment was performed by Trowbridge, Moulton, and Haigh,[106] in which they report, "When young beef animals in good condition are put on a ration insufficient to provide for a normal growth there is a very persistent tendency to grow in spite of the feed restrictions. Much of the surplus fat will be used for energy, and growth of both lean flesh and skeleton will continue. Later, with continued feed restrictions, the animal will draw on both the residual fat supply of the soft parts and also on the protein of the soft parts, to maintain existence and to promote a normal growth of the skeleton, which even includes the storing of fat in the skeleton. As the fat supply of the soft parts becomes more seriously depleted, and when the animal has drawn heavily on the protein structure of the soft parts in order to preserve existence, the animal is able to draw on the fat supply of the skeleton until that structure is almost entirely robbed of its storage of fat."

Because[107] of the "growth impulse" such an underfed young animal burns his reserve of body material to cover the deficit in the energy intake in his endeavor to grow at a normal rate. Such a condition continued indefinitely results after a time in cessation of all growth and finally death from starvation.

Thus it is clear that a deficient energy supply effects the well-being of the animal materially. On the other hand, an excess of energy in the ration does not harm the animal, but the excess is deposited in the body as fat. Consequently the experienced feeder can control the energy supply so as to induce the desired amount of growth.

Mineral Matter. The mineral elements have long been recognized as playing an important part in the growth of young animals, however the subject is just beginning to receive the attention which it deserves. The idea long prevailed that the mineral constituents are contained in abundance in ordinary feeding-stuffs and that no danger existed from any shortage in supply. This view probably accounts for the scant attention given this subject until recent years.

With the increasing use of the grains and cereals for human consumption, large industries have developed, engaged in the separation of these grains into their many parts. This results in a return to the form of by-products, the mineral content of which may be much gfeater or smaller than the original product from which it was derived. All this necessitates an understanding of their function in nutrition, and consequently a more careful consideration of the mineral content of these feeds available to the farmer.

The minerals[108] calcium, magnesium, potassium, sodium, phosphorous, sulphur, iron, and chlorine are required in varying proportions by all animals, and of these[109] the elements most likely to be deficient are calcium, phosphorous, and iron. Osborne and Mendel[110] observed that the lack of sufficient minerals in the diet was promptly exhibited in a cessation or restriction of growth, while Henry and Morrison[111] claim that if an animal is fed a ration free from mineral matter, it will generally die sooner than when no food is given.

Since these elements are so essential to the diet, it becomes interesting to review their functions in general animal metabolism as outlined by Forbes.[112] They are as follows:

"As bearers of electricity the mineral elements dominate the whole course of metabolism.

They conduct nerve stimuli, and play a leading role in the general process of cell nutrition.

They govern the contraction of the muscles, including those of the heart.

They compose this central agency for the maintenance and neutrality in the blood.

They enter into the composition of every living cell.

They compose supporting structures.

They assist in coordination of the digestive processes.

They activate enzymes, and thru their control of the chemical reaction of the blood and tissues they govern enzyme action.

They unite with injurious products of metabolism, and render them harmless or useful.

As catalyzers they alter the speed of reactions, and the rate of metabolism generally as measured by oxygen consumption.

Thru their effect on osmotic pressure they govern the movement of liquids and maintain the proper content of the tissues.

Thru their effect on surface tension they participate in the mechanism of cell movement.

Thru their control of the inhibition of water by the colloids they govern respiration.

Finally, they control the state of solution, precipitation, mechanical aggregation of the colloids which compose living tissue."

Armsby[113] states, "The growing animal, like the mature one, requires mineral ingredients to supply and maintain certain conditions indespensible to the performance of the bodily functions, but in addition to this, the formation of new tissue and especially of the skeleton involves the storage of ash ingredients, which must be derived from the feed."

After an extensive study of some of our more common feeds, Forbes[109] shows that the two elements probably to be insufficient to supply the demands of the animal are calcium and phosphorous. Hart, Steenbock, and Fuller[108] state, "Under general farm conditions where the animals are fed according to the feeding standards, the abundant use of concentrates is very liable to decrease the calcium supply to within the danger limits. In case of phosphorous the danger is not quite so imminent and is always lessened with increased amounts of grain in the ration." Forbes[114] also shows that altho a feed analysis may show an abundance of these elements present, a deficient utilization of them by the animal is generally observed, and thus the supply of utilizable elements, especially calcium under certain conditions becomes dangerously near a critical point.

It seems probable that an inadequate supply of calcium in the food during growth retards the development and calcification of the bones. This appears to have been demonstrated by Evard,[115] Dox, and Guernsey by the addition of calcium chloride and calcium carbonate to a basal ration of corn and common salt, in the case of pregnant swine resulted in greater size, more vigor, and better general condition of the new born pig.

Bone development may also be interfered with by inadequacy of the phosphorous supply. In experiments of Hart, McCollum, and Fuller[116] young pigs on phosphorous-poor food continued to grow for some time but finally developed not only the bone defect, but also weakness of the legs, stupor, dragging of the hind quarters, and ultimately loss of weight and collapse. These effects were all prevented by simple additions of calcium phosphate to the food. In another experiment Hart[117] and McCollum report, "When swine are restricted to corn meal and gluten feed, little or no growth can be secured, but with an addition of salts making the entire ash content of the ration very similar in quality to that of milk, growth approximating that of normal was secured."

Pearl[118] reports feeding calcium lactate and lactophosphate in small doses to growing chicks. The males were not effected, but the females showed a marked augmentation of growth. He further reports that indications are that calcium plays an important role in the reproductive functions of the female.

Most of this work has been carried out either on mature cows or on animals of different species. However, Eckles fed two Jersey heifers approximately six months old, one on a low calcium diet and the other a high calcium diet. The animal on the low mineral ration, as far as could be determined by appearance, thrived and apparently was in normal condition until she was nearly 18 months old and had been fed on the ration for 13 months. The first indication was a stiffness in the joint and an abnormal gait in walking which gradually became worse until the animal walked with the knees partially bent, and she could not get up from a lying position except with great difficulty. By making a decided change in the ration and by giving bone meal liberally, it was possible to restore the condition of this heifer to nearly normal within a month. The heifer on normal made excellent growth and remained in splendid physical condition at all times. The result was that the animal which received the ration low in calcium made a perfectly normal growth both in height and weight, and made a growth equal to the animal receiving the high mineral ration.

Although we find that the mineral supply may be low at certain times of the season, Forbes,[114] states, "that the skeleton is able to store calcium and other elements in a time of an abundant supply, and the animal draws upon them in time of need." This is substantiated by the work of Hart, McCollum, and Humphrey,[121] who experimented on pigs and cows and conclude that "the skeletal tissue can vary its ash content within quite wide limits, thereby acting as a supply house over considerable periods of time for certain ash constituents that may be deficient in quantity in the food."

Besides being able to store the mineral elements, according to Osborne and Mendel, "The growing animal can fully supply from inorganic sources its requirements for the mineral elements." "This emphasizes anew that it is unnecessary to consider the presence of calcium, phosphorous and iron for example, in natural food, to the degree that is currently believed. Any shortage of an essential inorganic element can be suitably remedied under ordinary conditions by the use of its salts."

Since roughages are especially rich in calcium[122] and sodium, and the cereals and grains high in phosphorous, we find that in our ordinary farm rations they make good each others deficiencies. Ordinarily then we find that our growing heifers do not suffer materially from the lack of these elements.[123] However, if the season is dry or the crops are grown on rather poor or sandy soils, lime and phosphorous should be added to the ration.

Vitamines. Recent investigations in nutrition have shown that food furnishing a sufficient amount of protein, carbohydrates, fats and mineral matter may not always prove adequate for growth and maintenance. Some at least of the food materials which go to make up a complete diet must have properties other than those which have been previously considered in the study of nutrition. These substances, of unknown composition, have been termed "accessory substances" or "vitamines."

The vitamines, although present in certain food-stuffs in small quantities, play an important part in the metabolic cycle of an animal body. These substances are absolutely essential for the well being and even the life of the organism itself, and if the indispensible elements are lacking, or the foods ingested are deficient in vitamines, the animal cell is unable to maintain it activities, and continued deprivation leads to disease and unltimately to cessation of life.

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As food constituents the vitamines are characterized by a disproportion between the apparent importance of their functions and the amounts in which they are normally consumed. They are present in quantities far too small to constitute any appreciable contribution to the energy supply of the body. Whether they ultimately prove to be structural components of living tissues of which a supply is essential even though quantitatively unimportant, or whether they are found to act rather as catalysts[124] in certain normal processes of metabolism remains to be proven. It seems certain, because they function in such small amounts, that they must be put in a nutritive category different from any which would comprise the better known food-stuffs, such as proteins, fats, and carbohydrates.

The study of vitamines is by no means new, for as early as 1881 Lunin[125] experimented with mice upon a diet composed of food units in a pure condition. He found that whereas adult mice could live for several months in good health on a diet of milk, they invariably died if they received a ration composed of what he believed to be the essential ingredients of milk. He remarked, "Other substances indispensible for nutrition must be present in milk besides caseinogen, fat, lactose, and salts." In 1897[126] Eijkman made the discovery that pigeons fed solely upon polished rice, developed within three or four weeks a state of paralysis which he called polyneruitis. He found that when birds were given the entire rice kernel, or unpolished rice, the disease did not develop. It was found furthermore, that the administration of rice polishings to pigeons suffering from polyneuritis, caused prompt relief to their symptons. Following this work, we find that Fraser and Stanton[127] in 1907 employed alcoholic extracts of rice polishings for the relief of experimental polyneuritis. These fundamental observations attracted little attention until 1910 when Funk, who named the "accessory substances" "vitamines", took up the study of beri-beri and made an elaborate attempt to isolate and study the "curative" substances in rice polishings.

A new viewpoint was suggested by Hopkins in 1912. He had as early as 1906 conducted experiments in the feeding of mixtures of purified protein, carbohydrates, and fats, and mineral salts, and was aware of the fact that neither maintenance of body weight, nor growth could be secured with such diets. He then tried the addition of such amounts of milk as would furnish four per cent of the total dry matter of the food mixture and observed growth could proceed when such milk additions were made. Hopkins suggested the existence of certain unidentified food substances which were supplied by the milk, and to these he gave the name "accessory article of diet."

McCollum[128] and associates in 1914 at the University of Wisconsin succeeded in securing growth in young rats fed upon a mixture of purified food-stuffs when the mixture contained butterfat, but no growth when vegetable fat or body fat of animals were substituted. They then undertook a series of systematic feeding experiments and found that wheat plus butterfat failed to promote growth. From these and similar results, it seemed apparent that there must be two dietary factors jointly responsible for the poor nutrition of animals. These factors were respectively designated as the "Fat-soluble A" and "Water-soluble B" by McCollum and Kennedy. Additional evidence of the existence[129] of such factors rapidly accumulated, and their presence was confirmed by Osborne and Mendel and others. Since this time numerous investigators , experimenting with guinea pigs, in contradiction to McCollum and associates, have found that there is a third accessory food substance, namely "Water-soluble C".

Evidence that at least three classes of "vitamines" or "Accessory substances" exist, is at hand. These classes are:

1. Fat-soluble A, - present in butterfat, and cod liver oil, green leaves etc., which protects against xerophthalmia, (and possibly rickets), and which promotes growth.

2. Water-soluble B, - fairly widely distributed in cereals, grains, eggs, meat, etc., necessary to prevent polyneuritis in birds and beri-beri in man, and to promote growth.

3. Water-soluble C, - found largely in vegetables and fruits, and protects against scurvy in man and guinea pigs.

Practically all of our common foods contain either one, two or all of our known vitamines as follows:

The Distribution of the Accessory Factors in the Commoner Foodstuffs.[131]

Food	Fat-soluble A	Water-soluble B	Water-soluble C
Fats and Oils			
Butter	+++	0	
Cream	++	0	
Cod-liver oil	++	0	
Mutton Fat	++		
Beef fat	++		
Fish oils	++		
Meat and Fish			
Lean Meat	+	+	+
Liver	++	++	+

Table Continued.

Food	Fat-soluble A	Water-soluble B	Water-soluble C
Meat and Fish Cont'd.			
Kidneys	+ +	+	
Sweet breads and brain	+	+ +	
Milk and Cheese			
Milk, cow's whole, raw	++	+	+
Milk, cow's skim, raw	0	+	+
Condensed, sweetened	+	+	-(+)
Cheese whole milk	+		
Eggs			
Fresh	+ +	+ + +	?
Dried	+ +	+ + +	?
Cereals			
Wheat, maize, rice	+	+	0
Wheat, maize germ	+ +	+++	0
Wheat, maize bran	0	++	0
Linseed, millet	+ +	+ +	0
Soy beans, haricot beans	+	+ +	0
Vegetables and Fruits			
Cabbage, fresh	+ +	+	+ ++
Cabbage, dried	+	+	--(+)
Lettuce	+ +	+	
Spinach, dried	+ +	+	
Swede, raw			+ + +
Potatoes raw	+	+	+
Potatoes, cooked			+
Beans, fresh, scarlet runners, raw			+ +
Lemon Juice, fresh			+ ++

Table Continued.

Food	Fat-soluble A	Water-soluble B	Water-soluble C
Vegetables and Fruits Cont'd.			
Lemon Juice, preserved			very slight
Orange Juice, fresh			+ + +
Tomatoes, canned			+ +
Miscellaneous			
Yeast, dried		+ + +	
Yeast, extract and autolysed	?	+ + +	?0

Indications are that "fat-soluble A" which is synthesized in plants, but not synthesized in the animal body, and probably stored in association with the reserve fat supplies, is primarily a growth promoting substance,[132] as ill effects which follow a deficiency of the fat-soluble substance are more serious and far reaching when they occur in early life, particularly during the period when the young animal is dependent upon the mother. The factor seems to play a direct part in nutrition of the cell, thus stimulating growth. However, the need of the vitamines is not limited to young animals in general. Drummond[133] has shown that as young rats approach maturity their requirement becomes markedly less. They can even live without it in apparently good health for considerable time, but sooner or later they loose weight and often have eye disease. They show a distinct decrease in resistance to various infections, many deaths occurring. There is therefore every reason says Drummond, "That great care should be taken to ensure that dietaries of adults contain an adequate supply of food-stuffs in which the 'Fat-soluble A' is present."

The "Water-soluble B" vitamine[133] occurs more widely in plants than in animals, and is found especially in cereals and the eggs of birds where it is deposited, apparently as a reserve for the nutrition of the young offspring. This vitamine prevents the occurrence of beri-beri in man and analogous diseases in animals.[134] It is also necessary to promote growth in young animals. The result of a deficient supply of this vitamine in the diet of pigeons is recorded by McGarrison.[135] The body temperature gradually fell from a normal average of 107°F. to 98 or 99° F. Digestive processes were greatly impaired; starch was largely excreted unchanged. The different organs of the body lost weight strikingly, all except the adrenals, which gained, thymus most, then in order, testicles, spleen, ovary, pancreas, heart, liver, kidneys, stomach, thyroid, and brain. The testicles lost 93% and the ovaries 69% of the original weight. Drummond found that when male rats after as short a time as 14 days on a diet adequate except for B were mated with females on an adequate diet no pregnancies resulted.

With reference to the function and minimum requirements of the factors A and B for maintenance and growth McCollum and Simmonds[136] write as follows: "Our results indicate that there is no low plane of intake of either of these substances which can be said to maintain an animal without loss of vitality. When the minimum amount necessaty for the prevention of loss of weight is approached the life of the animal is jeopardized if the diet is persisted in."

"Within certain limits growth is proportional to the supply of the "fat-soluble A" and "water-soluble B" in the diet, all other factors being properly adjusted."

"The animal can tolerate being limited to a very low intake of either the dietary A or B much better with an otherwise excellent diet than when it is less well constituted."

"Without exception the records indicate that it is dangerous procedure to attempt to fast an individual selectively for one or both of these dietary essentials."

Water-soluble C, the third vitamine now recognized, is the anti-scorbutic. This vitamine is present in living vegetable and animal tissue in largest amounts in fresh fruits and green vegetables, and to a less extent in root vegetables and tubers. This vitamine is necessary in a diet for the prevention of scurvy in the guinea pig and man. Harden and Zilra[137] observed that rats thrive better with anti-scorbutic vitamine present in the diet than without it. In addition there are some positive results on monkeys. Collected data tend to show that this factor is necessary primarily as a nutritional factor, and is not essential as a growth promoter.

The fat-soluble A and water-soluble B are not so stable toward heat as we formerly supposed. It has been found that heating above 100 F. does cause deterioration, and that the treated food has to be supplied in larger quantities than the raw food. For example,[138] while wheat germ heated two hours at 100 F. loses little or none of its potency of B, heated 40 minutes at 113 F. it may lose up to nine-tenths. Similar[139] results have been secured on "A" by Steenbock, Boutwell, and Kent.[140] The factor "C" is more sensitive to high temperatures and destroyed "when the living tissue is disorganized by drying and other methods of preservation." Cooking seems to destroy the substance, and we find[141] tinned vegetables and tinned meat are also deficient in anti-scorbutic principle.

It is plain that, remarkable as are the advances in this subject, we still have far to go for anything approaching complete knowledge. This much is certain, the diet must contain certain amounts of these substances of unknown composition if maintenance and growth are to proceed normally.

Other Factors. It is a common observation by cattlemen that to prove satisfactorily over a long period of time, a ration must have certain characteristics, other than food ingredients. Among these are variety, succulence, palatability and bulkiness.

From the preceeding discussion it is apparent that individual feeds differ markedly in the amount of amino-acids, mineral elements and vitamines they contain, and in some feeds these essential ingredients are entirely absent. The various feeds do not lack the same ingredients. Hence we should expect that when two incomplete feeds were combined, the first might supplement the deficiencies of the second and better growth be made than on either alone.[142] This seems to be a common observation of successful feeders who usually maintain that a ration composed of a variety of feeds will give better results than when a smaller number are employed. That this is the case with proteins is clearly brought out by McCollum,[143] who tested a number of proteins and found that, while linseed meal fed as the sole source of protein was the least efficient of any of the feeds tested, when it was combined with corn the results were considerably better than with corn alone.

Numerous feeding trials and common experience on the farm have demonstrated the value of adding succulent feeds to the rations of farm animals, and especially the dairy cow. This beneficial effect of succulence can be supplied as pasturage, silage, soilage, or root crops. Henry and Morrison[144] state, "Just as our own appetites are stimulated by fruits and green vegetables, succulent feeds are relishes for the animals of the farm." They add, "Such feeds tend towards rapid sturdy growth with the young of all farm animals." Eckles holds[145] "that such feed has a value outside of the actual nutrients it contains, on account of the favorable effect upon the digestion of the animal."

Feeds are considered palatable when they are pleasant to the taste, and readily consumed by the animal. This factor[146] is greatly influenced and controlled by familiarity and habit of custom. When corn silage is first placed before animals they care very little for it, but gradually become accustomed, and later may gorge themselves upon it if permitted. Unpalatable feeds are refused to a large extent by animals, consequently this factor may influence the quantity of feed consumed, and thereby be a limiting factor in the growth of dairy heifers. Jordan[147] comments upon palatability as follows, "An agreeable flavor is not a source of energy or of building material, but it tends to stimulate the digestive and assimilative functions of the animal to their highest efficiency, as is a requisite for the consumption of the necessary quantity of food."

It is a recognized fact that a certain amount of bulk is desired in the ration to distend the digestive tract and thereby assist in satisfying the hunger of the animal; however, if the ration is too bulky the animal may not consume as many nutrients in the alloted bulk as are required for maintenance and growth. Consequently you would limit the growth of the animal. An example of this is silage. Heifers[148] eat silage readily up to a certain amount but if required to obtain a large part of the total nutrients from this source, they will not consume a sufficient amount to make normal growth.

ENERGY REQUIREMENTS FOR GROWTH.

Review and Discussion of Literature.

One cannot help being impressed with the remarkable progress that has been made in adding to our general knowledge of the nutrition of animals. Nevertheless, a review of the literature on this subject reveals the fact that there is a very small amount of material that has a direct bearing on the energy requirements for the normal growth of animals. Much of the experimental work which has been done concerns beef cattle chiefly. With this class of animals it is desirable tha growth should proceed at a somewhat more rapid rate than for dairy cattle. For this reason the results can be applied only in a limited way to dairy heifers.

Feeding Standards for Growth of Dairy Heifers. - A review of the different feeding standars discloses the fact that at present three types of standards set forth, in as many different ways, the requirements for animals. They are the Wolff-Lehmann, Kellner, and Armsby standards. Of these the latter two have calculated a separate standard for growing animals.

The Wollf-Lehmann[149] standard attempts to express the requirements of the animal in pounds of total dry substance, digestible crude protein, digestible carbohydrates, and digestible fat per 1,000 pounds live weight. The great objection to this type of standard is that it does not take into account the varying value of digestible matter in different feeding stuffs due to the losses of energy in the process of digestion and assimilation. Kellner's[150] standard expresses the requirements in a similar manner, except the value of the carbohydrates is stated in terms of starch equivalent. The starch equivalent and fat may be converted into net energy values as one pound of starch equivalent will produce approximately 1071 calories of energy. This standard has been used but very little in this country.

The first standard based on the energy values of feeds was published by Armsby[151] in 1909. This standard expressed the requirements of animals in terms of true protein and therms of net energy. The requirements[152] as set forth by this standard were later revised to supposedly meet the requirements of growing animals, and published in 1916. However, the following year Armsby[153] came out with another modification of his standard for growing animals, setting forth the energy requirements as in his 1916 standard, but reducing the protein requirement from 15 to 30% varying with the age from 3 to 30 months respectively. The present protein requirement is based on Kellner's standard.

Armsby further gives standards for growth showing the energy value of one pound of gain in weight by growing cattle. This, however, is based upon a very limited amount of data. Armsby[154] comments upon it as follows:,"No very extensive determinations of the composition and energy of the increase of live weight in growing animals have yet been reported. The accompanying estimates cannot lay claim to any high degree of accuracy."

When studying these standards and comparing rations formulated according to the requirements as set as set forth by them for animals of the same weight, we find wide variations in the amount of feed supplied the animal. This, together with the frequent revisions being made by the author, would tend to show that the various standards do not satisfactorily apply to the growing animal.

Energy Requirements for Maintenance and Growth.- A study of the literature on this subject reveals the fact that there is little definite information at hand. Few actual feeding trials have been carried out with growing cattle.

Haecker[155] kept feed records of steers to determine the feed required in the rearing and fattening of steers up to two years of age. With beef cattle it is desirable that growth should proceed at a somewhat more rapid rate than for dairy cattle. Upon examining the feed records we find that the animals gained more than the normal for dairy heifers of this age and weight; and they consumed more therms of energy for their weight than is set forth by Armsby in his standard. For this reason the results are of no particular value in our study of the energy requirements for the normal growth of dairy heifers.

Norton[156] gives the record of the feed required to grow a large number of heifers. The animals were mostly Holsteins, the others being Shorthorns, Guernseys and Jerseys. The nutrients of the total ration for 12 months is calculated in energy values and pounds of digestible protein from the data presented in the bulletin. The animals gained weight at the rate of 1.57 pounds daily during the first year of their life. It required 2.93 therms of energy for each pound of gain as compared to three therms as alloted by Armsby's standard.

Wing[157] kept feed records on three lots of calves of three each up to the age of 180 days. Lot I was fed in the usual manner on skim milk, hay and grain. Lot II received powdered skim milk instead of the ordinary skim milk up to 120 days, when the milk was taken out of the ration. Lot III received identically the same ration as lot II except that the skim milk was withdrawn from the ration at the age of 90 days.

Lot I averaged 150 pounds for the period, made a gain of 106% as compared to the normal, on an average daily consumption of 2.73 therms of energy, which is 22% below the requirements as set forth by Armsby. Lot II averaged 142 pounds, made a gain of 91.2% as compared to the normal, on 2.83 therms of energy which is 19% under Armsby's figures. Lot III averaged 167 pounds in weight, made a gain of 98% as compared to the normal, on 3.01 therms of energy, 17% less energy than prescribed by Armsby.

An average for the three groups shows that the nine calves made an average gain of 98.5% as compared to the normal on 80.9% of the energy as is alloted by Armsby's present standard.

Another work that is directly appliable to the present study is reported by Eckles.[158] These data were taken at the Missouri Experiment Station during experiments covering five winters with regard to rations for wintering growing heifers and reported in Bulletin 158 of that Station. The data contained therein and directly related to the present study are tabulated below.

Results of Wintering Heifers.

	Exp. Animals	Energy	Energy Comp. to Armsby's Standard	Gain	Gain Comp. to Normal
		Therms	per cent	Pounds	per cent
Exp. 2. Group 3	3	4.84	80	0.71	90
Exp. 2. " 4	3	5.76	93	0.85	113
" 3. " 5	4	6.35	99	0.97	117
" 3. " 6	4	5.55	90	0.82	107
" 3. " 7	4	5.43	80	0.54	71
" 4. " 8	5	6.54	93	1.12	151
" 4. " 9	4	6.32	97	0.85	108
" 4. " 10	4	5.47	92	0.76	92
Total and Average	31	5.84	91	0.84	108

These different groups, or a total of 31 heifers were fed on rations of entirely different character. The rations were made up of a variety of feeds, and would appear to be satisfactory in every way, with two exceptions. In group 7 we find the ration too bulkyfor the animals to consume enough feed to give them the necessary amount of energy; while in group 10 was fed timothy hay, which is unpalatable, and again the animals could not be made to consume enough food. In both cases the energy consumed was materially less than called for by the standard. In the majority of cases the protein supply was greater than the requirements as stated by Armsby, however, we find groups 3 and 6 receiving less than the amount called for. Even with the protein at this low figure and the energy 10% less than the standard calls for, we find group 6 making an average daily gain of 107% as compared to normal. This would tend to show that the protein supply in these trials was not so small as to be a limiting factor in the growth of the animal. The summary shows that the 31 heifers were on the average underfed 9% in energy as compared to Armsby's standard, and on this supply made an average daily gain of 108% as compared to normal.

The foregoing results seem conclusive enough to the writer to lead him to believe that the supply of energy as now set forth by Armsby's standard is higher than necessary, and that a further study of the subject will reveal sufficient evidence to necessitate a further revision of his present standard.

Experimental Work.

One of the problems confronting the present day breeder and grower of dairy cattle is the rearing of the young heifers to replace the discarded cows. Although recent study has shown that protein, mineral matter, vitamines and other factors are essential for growth and development, it has long been recognized that the animal requires a certain amount of total food or energy, which must contain these other ingredients. Observations and investigations as to the energy requirements of growing cattle tend to show that the requirements as set forth by our present standards are unnecessarily high, and, because of the increased cost of feeds with high energy value, the question is of greater economic importance than formerly when feeds were on a much lower price level.

Object of the Experiment.- The object of this investigation is to study the energy requirements for the normal growth of dairy heifers. This requirement is not only that contained in the body increment resulting from growth, but in addition includes the net energy required for maintenance, the sum of the two being the total net energy required by the growing animal.

The writer realizes that the data at hand do not represent a large enough number of animals to justify definite conclusions. However, it is hoped that the data taken will be a contribution to the general knowledge of the subject and will at least serve to indicate whether the energy requirement as prescribed by Armsby approximates the true figure.

Methods of Study.- Two methods of studying this problem of nutrition may be followed. First the so-called balance experiment, in which the income of energy from the food is compared with the outgo in the various excreta and the heat evolved. So far as the visible excreta are concerned, such a comparison involves no special technical difficulties, but to insure accuracy the comparison must be extended to the gaseous excreta and the heat. Here special forms of costly apparatus are necessary. The second method is the feeding trial, where accurate records are kept of the feed consumed and gains made by a large number of growing animals under normal conditions. This method was followed in the present investigation. There is every reason to believe that the results obtained in this manner are reasonably safe if a sufficiently large number of animals are used over a long period of time.

Plan of Trial.- In planning how to determine the energy requirements for the normal growth of dairy heifers, it was decided to follow the Armsby method in calculatin all rations. Since a rather general impression prevails that the requirements as furnished by the Armsby standard are higher than is necessary to secure normal growth, it was deemed advisable to divide the heifers into two groups according to their age, weight and breed, as will be found in table 18. One group was to receive protein and energy according to Armsby's standard, and the second group to receive protein according to the Armsby standard and energy 15% below. The trial was planned to cover from 100 to 120 days. The average daily gains secured were to be compared to the normal, and thereby determine whether the requirements as now set forth could be satisfactorily followed in feeding the dairy heifer.

The protein requirement as set forth by Armsby's present standard is based on Kellner's standard. The present writer is uncertain whether the requirement is expressed as true or crude protein. Since results from previous feeding trials had demonstrated that heifers receiving even less crude protein than prescribed by the standard were making more than normal growth, it was decided to calculate all rations on the crude protein basis.

Heifers Used.- Twenty pure-bred heifers of the University herd were used. Of the total three were Ayrshires (Nos. 8, 9, 10); six Holsteins (Nos. 339, 341, 342, 345, 346, 347); two Guernseys (Nos. 510, 511); and nine Jerseys (Nos. 123, 124, 125, 126, 127, 128, 129, 130, 131). A detailed description of these animals is given in table 18.

Rations Used.- The feed making up the ration were so selected as to be easliy duplicated under farm conditions, and at the same time embody the essential factors for a complete ration as now understood. The ration consisted of prairie hay, corn silage, dent corn, wheat bran, and oil meal.

The corn and wheat bran were mixed equally by weight, and are hereafter referred to as the grain mixture. The oil meal was fed in varying amounts so as to furnish the necessary protein required. For this reason it was found impractical to include this ingredient in the grain mixture, and at the same time keep the protein supply reasonably near the amount called for.

This ration furnishes protein from four different sources and combines feeds low in protein with those high in this constituent. The mixture supplies proteins of good variety and quality, and the supplementary effect is satisfactory from an economical standpoint. This ration has the common fault of most farm rations, that is, a shortage of inorganic matter, but the feeding period does not extend over a long enough time to bring this factor in. The hay and silage furnish fat-soluble A, and the grains also contain a trace of this constituent, so the needs of the animal should be sufficiently cared for. All the feeds supply abundantly the water-soluble B, while the hay and silage furnish the water-soluble C. The ration, as will be noted, furnishes a variety of feeds; succulence in the silage, sufficient bulk in the sialge and hay, and a mixture of feeds making a palatable ration.

Methods of Feeding.-- All feed was weighed and any portion rejected was carefully weighed and recorded. No effort was made to keep the ratio between the concentrates and roughages the same, but instead it was the aim to feed all the roughage the animals would clean up, and make up the balance of the protein and energy requirement with the grain mixture and oil meal.

All the animals were fed according to the Armsby standard for a preliminary period of ten days, after which time they were divided into two groups, the first group being fed protein and energy according to the Armsby standard, and the second group was fed protein according to the standard and energy 15% below. Both groups received the same feeds in their ration, only in different proportions.

Water and salt were available at all times when the heifers were out for exercise, which was from about 10 A.M. to 3 P.M. daily when the weather permitted.

The feeding hours were regular, at six o'clock in the morning and five o'clock in the afternoon.

Weighing and Measuring.- The heifers were weighed when put on experiment, at the end of the preliminary ten-day trial, after the first twenty days on experiment, and thereafter at regular thirty-day intervals until the trial was completed. The weights were taken for three successive days, and an average of the three weights used. This does away to a large extent with the daily fluctuations.

The plan at the start of the experiment was to continue the trial for 90 days only. Since skeletal growth is so slow it was decided to use the gain in weight as the only measure of growth. However, before the trial was completed it was deemed advisable to measure the height at withers at the close of the experiment. Three measurements were taken of each animal at the highest point of the withers. The animal was moved about before each measurement, so as to make certain that the animal had not settled at the withers. An average of the three was used as the height measurement.

Discussion of Data.

The purpose of this investigation is to contribute, if possible, additional data on the energy requirement for the normal growth of dairy heifers. Such an investigation deals primarily with the nutrients consumed and the growth of the animal. In order to know whether or not these trials were successful, it was necessary to have some standards of comparison, since no check animals were used in the experiment. The nutrients consumed were compared to Armsby's standard, while the growth was compared to normal growth figures for each particular breed. Such standards on growth were compiled from weights and measurements taken on a large number of animals of the different breeds at the Missouri Experiment Station. Because these figures are averages of those taken from many animals, the factor of individuality is eliminated. Table I[159] was adopted from unpublished data of the above Experiment Station and embodies the figures used in this thesis wherever normal growth is referred to.

Calculations relating to the composition of feeds used are based on Armsby's[160] tables. His figures for digestible crude protein are used instead of those for digestible true protein.

The data by 30 day periods for each of the twenty heifers are given in tables 2 to 17 inclusive. Data concerning group 1, receiving protein and energy according to Armsby's standard, are contained in tables 2 to 9. These tables give the age and weight of the animal, the kind and amounts of feed consumed, the gain in weight secured on this feed, and a comparison of the nutrients consumed with Armsby's standard. Tables 10 to 17 inclusive refer to Group 2, receiving protein according to Armsby's standard and energy 15% below. As stated for Group 1, the tables give the age and weight of the animal, the kind and amount of feed consumed, the gain in weight secured on this feed and a comparison of the protein received with Armsby's standard, while the energy supply is compared to Armsby's standard -15%.

A summary of the results of the two groups is given in table 18. This table gives the number of the animal, the age and weight at the beginning of the trial, ration as compared to Armsby's standard, the gain secured and a comparison of the gain with the normal. The table further gives the averages for each group, so as to afford data to compare the results from the two groups.

A tabulation of the data on relation of breed to the gain in weight is found in table 19. This table gives the number of animals of each breed in the two different groups, the average gain in weight by each breed by groups, and a comparison of this gain to the normal. Furthermore an average is given for the different breeds in each group, and an average of the results of the two groups.

Data concerning the relation of age to gain in weight are given in table 20, consisting of the age of the animals at the beginning of the trial, the number of animals used for eadh age, and the gain secured compared to the normal.

Photographs of representative animals used in this experiment may be found following page 88.

TABLE 1

NORMAL WEIGHTS AND MEASUREMENTS FOR DAIRY HEIFERS.

Age	HOLSTEINS		JERSEYS		AYRSHIRES	
	Weight	Height at withers	Weight	Height at withers	Weight	Height at withers
Months	Pounds	Centimeters	Pounds	Centimeters	Pounds	Centimeters
6	349	100.9	260	93.7	286	92.6
7	389	104.0	302	96.8	304	94.8
8	425	107.1	340	99.8	336	97.8
9	466	109.1	376	102.8	366	99.1
10	501	111.2	407	105.0	406	100.8
11	529	112.6	432	106.5	427	101.0
12	558	114.0	456	108.3	456	103.5
13	574	115.7	480	110.1	486	105.0
15	596	117.4	503	111.4	533	106.8
15	612	118.8	520	112.7	547	107.8
16	643	120.3	533	113.4	560	108.5
17	660	121.3	553	114.6	579	109.5
18	686	121.8	572	115.6	604	111.2
19	715	122.7	598	116.8	627	112.3
20	746	123.8	621	117.5	651	113.4
21	774	124.3	649	118.1	679	114.1
22	796	124.9	668	118.9	707	115.3
23	824	125.7	689	119.8	733	115.9
24	841	126.5	716	120.4	759	116.5

TABLE 2

GROUP RECEIVING PROTEIN AND ENERGY ACCORDING TO ARMSBY'S STANDARD.

Feed Consumed Daily
and
Daily Gain in Weight.

30 day periods.

	Prairie Hay	Corn Silage	Grain Mixture	Oil Meal	Gain in Weight	
					Actual	Normal
No. 8	Pounds	pounds	Pounds	Pounds	Pounds	Pounds
	* 6	15	2.4	0.7	1.15	1.60
	7	14	2.7	0.5	0.73	0.56
	7	16	2.8	0.4	1.27	0.43
	7	18	2.6	0.4	1.33	0.63
Total	750	1740	291.0	530.0	122.0	65.0
Average	6.8	15.8	2.64	0.48	1.11	0.59
No. 10						
	* 6	13	2.3	0.8	1.52	0.96
	6	15	2.4	0.7	0.80	1.60
	6	16	2.6	0.6	1.66	0.56
	7	16	2.8	0.4	1.03	0.43
Total	690	1670	280.0	67.0	137.0	85.0
Average	6.3	15.2	2.54	0.61	1.27	0.77
No. 341						
	* 7	18	2.8	0.3	0.70	0.53
	7	18	3.2	0.2	1.00	1.03
	7	18	3.5	0.1	1.06	0.56
	8	18	3.4	0.0	1.10	0.87
Total	800	1980	359.0	15.0	107.00	96.0
Average	7.3	18.	3.26	0.14	0.97	0.87

*Note - 20 days only/

TABLE 3

GROUP RECEIVING PROTEIN AND ENERGY ACCORDING TO ARMSBY'S STANDARD.

Record of Weights
and
Comparison of Nutrients Consumed with Armsby's Standard.

Average per day for 30 day periods.

	Age	Weight	Weight compared to Normal	Dig. Crude Protein: Armsby's Standard	Dig. Crude Protein: Supplied	Net Energy: Armsby's Standard	Net Energy: Supplied
No. 8	Months	Pounds	per cent	Pounds	Pounds	Therms	Therms
	* 14	648	120	0.850	0.856	7.200	7.095
	15	670	121	0.850	0.855	7.360	7.361
	16	699	123	0.850	0.856	7.594	7.668
	17	738	125	0.850	0.858	7.820	7.740
Average		691	123	0.850	0.856	7.520	7.499
No. 10							
	* 13	606	119	0.850	0.855	6.836	6.796
	14	634	117	0.850	0.856	7.070	7.095
	15	669	121	0.850	0.857	7.353	7.303
	16	711	124	0.850	0.856	7.668	7.668
Average		659	120	0.850	0.856	7.268	7.254
No. 341							
	* 15	756	120	0.850	0.848	7.933	7.899
	16	777	119	0.850	0.858	8.062	8.085
	17	807	119	0.850	0.858	8.242	8.203
	18	839	120	0.850	0.858	8.440	8.449
Average		798	119	0.850	0.856	8.190	8.188

* Note - 20 days only.

TABLE 4

GROUP RECEIVING PROTEIN AND ENERGY ACCORDING TO ARMSBY'S STANDARD.

**Feed Consumed Daily
and
Daily Gain in Weight.**

30 day periods.

	Prairie Hay	Corn Silage	Grain Mixture	Oil Meal	Gain in Weight	
					Actual	Normal
No. 345	Pounds	Pounds	Pounds	Pounds	Pounds	Pounds
	* 5	11	2.5	0.9	0.15	1.36
	6	12	2.4	0.8	1.33	1.16
	6	14	2.7	0.6	1.10	0.93
	6	16	2.6	0.6	2.22	0.96
Total	640	1480	281.0	78.0	171.00	122.0
Average	5.8	13.4	2.55	0.71	1.55	1.11
No. 347						
	* 5	11	2.2	1.0	1.70	1.20
	6	12	2.3	0.8	1.10	1.36
	6	12	2.9	0.6	1.93	1.16
	6	16	2.6	0.6	1.87	0.93
Total	640	1420	278.0	80.0	181.00	128.0
Average	5.8	12.9	2.53	0.73	1.61	1.16
No. 126						
	* 5	10	2.2	1.0	1.05	0.80
	5	11	2.3	1.0	0.93	0.80
	6	10	2.6	0.8	0.87	0.76
	6	13	2.3	0.8	1.06	0.56
Total	610	1220	260.0	98.0	107.00	80.0
Average	5.5	11.1	2.36	0.81	0.97	0.73

*Note - 20 days only.

TABLE 5

GROUP RECEIVING PROTEIN AND ENERGY ACCORDING TO ARMSBY'S STANDARD.

Record of Weights
and
Comparison of Nutrients Consumed with Armsby's Standard.

Average per day for 30 day periods.

	Age	Weight	Weight compared to Normal	Dig. Crude Protein: Armsby's Standard	Dig. Crude Protein: Supplied	Net Energy: Armsby's Standard	Net Energy: Supplied
No. 345	Months	Pounds	per cent	Pounds	Pounds	Therms	Therms
	* 8	557	125	0.850	0.842	6.457	6.301
	9	592	122	0.850	0.854	6.738	6.706
	10	628	122	0.850	0.845	7.028	7.054
	11	679	125	0.850	0.857	7.433	7.303
Average		619	123	0.850	0.850	6.955	6.810
No. 347							
	* 7	548	133	0.850	0.843	6.390	6.178
	8	581	131	0.850	0.844	6.637	6.637
	9	627	127	0.850	0.844	7.020	6.875
	10	684	133	0.850	0.857	7.473	7.303
Average		615	132	0.850	0.847	6.924	6.800
No. 126							
	*11	512	115	o.837	0.832	6.060	6.019
	12	537	114	0.845	0.853	6.270	6.248
	13	564	114	0.850	0.851	6.520	6.527
	14	593	115	0.850	0.845	6.739	6.736
Average		555	114	0.850	0.846	6.440	6.415

*Note - 20 days only.

TABLE 6

GROUP RECEIVING PROTEIN AND ENERGY ACCORDING TO ARMSBY'S STANDARD.

Feed Consumed Daily
and
Daily Gain in Weight.

30 day periods.

	Prairie Hay	Corn Silage	Grain Mixture	Oil Meal	Gain in Weight	
					Actual	Normal
No. 129	Pounds	Pounds	Pounds	Pounds	Pounds	Pounds
	* 4	10	2.0	1.2	1.20	.80
	5	10	2.3	1.0	0.73	.80
	5	11	2.5	0.9	1.00	.76
	5	12	2.5	0.9	1.43	.56
Total	530.	1190	259.0	108.0	119.00	80.0
Average	4.8	10.8	2.35	0.98	1.09	0.73
No. 124	* 5	11	2.5	0.9	0.90	0.80
	6	10	2.6	0.8	0.87	0.76
	6	13	2.3	0.8	0.83	.56
	6	14	2.2	0.8	0.76	.43
Total	640	1330	263.2	128.0	91.00	70.0
Average	5.8	12.1	2.31	1.16	0.82	0.64
No. 130	* 4	8	1.5	1.3	1.30	0.82
	4	10	1.9	1.2	0.53	0.80
	4	10	2.0	1.2	0.56	0.80
	5	9	2.2	1.0	0.70	0.76
Total	470.0	1030.	213.0	128.0	80.0	88.0
Average	4.3	9.4	1.94	1.16	0.73	0.80

*Note - 20 days only.

TABLE 7

GROUP RECEIVING PROTEIN AND ENERGY ACCORDING TO ARMSBY'S STANDARD.

Record of Weights
and
Comparison of Nutrients Consumed with Armsby's Standard.

Average per day for 30 day periods.

	Age	Weight	Weight compared to Normal	Dig. Crude Protein: Armsby's Standard	Dig. Crude Protein: Supplied	Net Energy: Armsby's Standard	Net Energy: Supplied
No. 129	Months	Pounds	per cent	Pounds	Pounds	Therms	Therms
	* 11	485	109	0.828	0.832	5.836	5.659
	12	508	108	0.836	0.842	6.040	6.092
	13	534	111	0.845	0.843	6.263	6.301
	14	570	111	0.850	0.854	6.560	6.460
Average		528	109	0.841	0.843	6.205	6.171
No. 124							
	* 12	543	116	0.847	0.843	6.340	6.301
	13	565	115	0.850	0.851	6.520	6.527
	14	590	115	0.850	0.845	6.720	6.736
	15	615	116	0.850	0.855	6.920	6.985
Average		581	115	0.849	0.849	6.651	6.668
No. 130							
	* 10	429	102	0.809	0.810	5.360	5.222
	11	450	101	0.817	0.823	5.533	5.588
	12	467	100	0.822	0.832	5.675	5.658
	13	486	97	0.828	0.821	5.840	5.860
Average		460	99	0.819	0.821	5.624	5.620

*Note - 20 days only.

TABLE 8

GROUP RECEIVING PROTEIN AND ENERGY ACCORDING TO ARMSBY'S STANDARD.

Feed Consumed Daily
and
Daily Gain in Weight
by
30 day periods.

	Prairie Hay	Corn Silage	Grain Mixture	Oil Meal	Gain in Weight: Actual	Gain in Weight: Normal
No. 510	Pounds	Pounds	Pounds	Pounds	Pounds	Pounds
	* 5	9	2.2	1.0	1.33	None
	4	6	3.9	0.7	0.60	"
	4	8	4.3	0.6	1.10	"
	5	8	4.4	0.4	1.23	"
Total	400.	900	393.0	71.0	115.00	"
Average	4.4	8.18	3.56	0.65	1.04	"

* Note - 20 days only.

TABLE 9

GROUP RECEIVING PROTEIN AND ENERGY ACCORDING TO ARMSBY'S STANDARD.

Record of Weights
and
Comparison of Nutirents Consumed with Armsby's Standard.

Average per day for 30 day periods.

	Age	Weight	Weight compared to Normal	Dig. Crude Protein: Armsby's Standard	Dig. Crude Protein: Supplied	Net Energy: Armsby's Standard	Net Energy: Supplied
No. 510	Months	Pounds	per cent	Pounds	Pounds	Therms	Therms
	* 12	503	---	0.834	0.821	6.020	5.860
	13	526	---	0.843	0.849	6.193	6.211
	14	551	---	0.850	0.869	6.407	6.298
	15	586	---	0.850	0.848	6.687	6.693
Average		549		0.845	0.846	6.354	6.330

* Note - 20 days only.

Group 1, Receiving Protein and Energy According to the Armsby Standard.- This group was fed according to the Armsby standard, and in no case did the protein vary more than 0.006 lb., less than 1%, from the requirement, and in all cases except one the energy supply was below the requirement. In no case did the energy supplied vary more than 2.1% from the amount required.

Ayrshire heifer number 8 weighed 691 lbs. for the average of the period and made an average daily gain of 1.11 lbs. which was 188% as compared to the normal.

Ayrshire heifer number 10 with an average weight of 659 lbs. for the period, made an average daily gain of 1.27 lbs. or 164% as compared to the normal.

Holstein heifer number 341, averaging 798 lbs. in weight for the period, made an average daily gain of 0.97 lbs., which represents an increase of 111% as compared to the normal for that period.

Holstein heifer number 345 averaged 619 lbs. in weight for the period, and made an average daily gain of 1.55 lbs. which is a gain of 139% as compared to the normal.

Holstein heifer number 347 with an average weight of 615 lbs. for the period, made an average daily gain of 1.61 lbs. which represents an increase in weight of 139% as compared to the normal for that period.

Jersey heifer number 126 weighed 555 lbs. for the average of the period, and made an average daily gain of 0.97 lbs. which is 133% as compared to the normal for her age.

Jersey heifer number 129 with an average weight of 528 lbs. for the period, made an average daily gain of 1.09 lbs., which represents an increase in weight of 149% as compared to the normal for that age.

Jersey heifer number 124 averaged 581 lbs. in weight for the period, and made an average daily gain of 0.82 lbs. or a gain of 128% as compared to the normal.

Jersey heifer number 130 with an average weight of 460 lbs. for the period made an average daily gain of 0.73 lbs., or a gain of 91% as compared to the normal for her age. This is the only animal in group 1 that made less than 100% gain as compared to the normal.

Guernsey heifer number 510, averaging 549 lbs. for the period, made an average daily gain of 1.04 lbs. Although no normal growth figures are available for this breed, a comparison of the gain to the other breeds would lead the writer to believe that the gain was greater than the normal.

A summary of the growth figures for this group is given in table 18. The average weight of the ten heifers for the period was 546 lbs. They made an average gain of 1.11 lbs., which represents a gain of 138% as compared to the normal.

TABLE 10

GROUP RECEIVING PROTEIN ACCORDING TO ARMSBY'S STANDARD, ENERGY 15% BELOW.

Feed Consumed Daily
and
Daily Gain in Weight
by
30 day periods.

	Prairie Hay	Corn Silage	Grain Mixture	Oil Meal	Gain in Weight Actual	Gain in Weight Normal
No. 9	Pounds	Pounds	Pounds	Pounds	Pounds	Pounds
	* 5	10	2.1	1.1	1.90	0.56
	5	12	2.2	1.0	0.37	0.43
	5	12	2.5	0.9	1.00	0.63
	6	13	1.9	0.9	0.93	0.83
Total	580.	1310	240.0	106.0	107.00	0.83
Average	5.3	11.9	2.18	0.96	0.97	0.59
No. 339	* 6	12	2.0	0.9	0.20	1.03
	6	13	1.9	0.9	0.97	0.56
	6	14	1.9	0.9	1.07	0.87
	6	14	2.2	0.8	2.13	0.97
Total	660	1470	211.0	93.0	129.00	96.0
Average	6.	13.4	1.92	0.84	1.17	0.87
No. 342	* 6	12	2.0	0.9	1.15	0.73
	6	14	1.9	0.9	1.07	0.53
	6	14	2.2	0.8	0.93	1.03
	7	16	1.6	0.8	1.26	0.56
Total	690.	1560.	201.0	93.0	121.00	79.0
Average	6.3	14.2	1.83	0.84	1.10	0.72

*Note - 20 days only.

TABLE 11

GROUP RECEIVING PROTEIN ACCORDING TO ARMSBY'S STANDARD,
ENERGY 15% BELOW.

Record of Weights
and
Comparison of Nutrients Consumed with Armsby's Standard.

Average per day for 30 day periods.

	Age	Weight	Weight compared to Normal	Dig. Crude Protein: Armsby's Standard	Dig. Crude Protein: Supplied	Net Energy: Armsby's Standard -15%	Net Energy: Supplied
No. 9	Months	Pounds	per cent	Pounds	Pounds	Therms	Therms
	*14	649	120	0.850	1.852	6.113	6.043
	15	674	121	0.850	0.854	6.290	6.341
	16	694	122	0.850	0.854	6.420	6.460
	17	723	122	0.850	0.845	6.540	6.607
Average		688	121	0.850	0.851	6.361	6.392
No. 339							
	*15	705	112	0.850	0.853	6.485	6.518
	16	736	113	0.850	0.845	6.640	6.607
	17	752	112	0.850	0.856	6.725	6.766
	18	800	114	0.850	0.856	6.970	6.896
Average		752	113	0.850	0.852	6.725	6.705
No. 342							
	*13	735	124	0.850	0.854	6.640	6.518
	14	762	126	0.850	0.855	6.773	6.766
	15	792	126	0.850,	0.856	6.930	6.896
	16	820	126	0.850	0.856	6.930	6.896
Average		781	126	0.850	0.853	6.886	6.854

*Note - 20 days only.

TABLE 12

GROUP RECEIVING PROTEIN ACCORDING TO ARMSBY'S STANDARD, ENERGY 15% BELOW.

Feed Consumed Daily
and
Daily Gain in Weight
by
30 day periods.

	Prairie Hay	Corn Silage	Grain Mixture	Oil Meal	Gain in Weight Actual	Gain in Weight Normal
No. 346	Pounds	Pounds	Pounds	Pounds	Pounds	Pounds
	* 3	7	1.7	1.5	1.00	1.20
	4	8	1.4	1.5	1.13	1.36
	4	8	1.8	1.4	0.93	1.16
	4	10	1.7	1.4	1.33	0.93
Total	420.	920.	181.0	159.0	121.00	127.0
Average	3.8	8.3	1.64	1.44	1.10	1.16
No. 123						
	* 4	8	1.4	1.5	0.43	0.56
	4	9	1.6	1.4	0.53	0.43
	4	8	2.1	1.3	0.76	0.66
	4	10	1.7	1.4	0.90	0.63
Total	440	970.	190.0	153.0	75.00	62.0
Average	4.0	8.8	1.73	1.48	0.68	0.56
No. 127						
	* 3	8	1.8	1.5	1.33	0.80
	4	8	1.7	1.4	0.27	0.80
	4	8	1.8	1.4	0.83	0.76
	4	9	1.8	1.4	0.93	0.56
Total	420.	910.	195.0	156.0	86.00	80.00
Average	3.8	8.3	1.77	1.42	0.78	0.73

* Note - 20 days only.

TABLE 13

GROUP RECEIVING PROTEIN ACCORDING TO ARMSBY'S STANDARD, ENERGY 15% BELOW.

Record of Weights
and
Comparison of Nutrients Consumed with Armsby's Standard.

Average per day for 30 day periods

	Age	Weight	Weight compared to Normal	Dig. Crude Protein: Armsby's Standard	Dig. Crude Protein: Supplied	Net Energy: Armsby's Standard -15%	Net Energy: Supplied
No. 346	Months	Pounds	per cent	Pounds	Pounds	Therms	Therms
	* 7	490	120	0.829	0.820	5.030	4.836
	8	517	118	0.838	0.841	5.220	5.192
	9	548	114	0.850	0.851	5.437	5.498
	10	582	111	0.850	0.862	5.650	5.627
Average		538	115	0.843	0.845	5.362	5.360
No. 123							
	* 14	522	102	0.840	0.841	5.251	5.192
	15	533	101	0.844	0.842	5.335	5.401
	16	554	102	0.850	0.851	5.470	4.498
	17	578	103	0.850	0.862	5.630	5.627
Average		549	102	0.846	0.849	5.437	5.451
No. 127							
	* 11	502	110	0.833	0.833	5.100	5.004
	12	518	110	0.838	0.841	5.220	5.311
	13	535	109	0.845	0.851	5.350	5.379
	14	561	109	0.850	0.861	5.508	5.529
Average		531	109	0.842	0.847	5.312	5.333

*Note - 20 days only.

TABLE 14

GROUP RECEIVING PROTEIN ACCORDING TO ARMSBY'S STANDARD, ENERGY 15% BELOW.

Feed Consumed Daily
and
Daily Gain in Weight
by
30 day periods.

	Prairie Hay	Corn Silage	Grain Mixture	Oil Meal	Gain in Weight	
					Actual	Normal
No. 128	Pounds	Pounds	Pounds	Pounds	Pounds	Pounds
	* 3	[illegible]	1.8	1.5	1.43	0.80
	4	9	1.6	1.4	0.40	0.80
	4	8	2.1	1.3	1.26	0.76
	4	11	1.8	1.3	0.73	0.56
Total	420.	1000.	201.0	150.0	99.00	80.00
Average	3.8	9.1	1.83	1.36	0.90	0.73
No. 12[illegible]	* 3	7	1.8	1.5	1.19	0.80
	4	8	1.4	1.5	0.63	0.80
	4	8	1.8	1.4	0.40	0.76
	4	9	1.7	1.4	1.16	0.56
Total	420.	890.	183.0	159.0	89.00	80.00
Average	3.8	8.1	1.66	1.44	0.81	0.73
No. 131	* 3	7	1.6	1.5	1.09	0.83
	3	7	1.8	1.5	0.50	0.80
	3	8	1.8	1.5	0.93	0.80
	4	8	1.4	1.5	0.83	0.76
Total	360.	1830.	182.0	165.0	89.00	88.00
Average	3.3	7.5	1.65	1.50	0.81	0.80

*Note - 20 days only.

TABLE 15

GROUP RECEIVING PROTEIN ACCORDING TO ARMSBY'S STANDARD, ENERGY 15% BELOW.

Record of Weights
and
Comparison of Nutrients Consumed with Armsby's Standard.

Average per day for 30 day periods.

	Age	Weight	Weight compared to Normal	Dig. Crude Protein: Armsby's Standard	Dig. Crude Protein: Supplied	Net Energy: Armsby's Standard -15%	Net Energy: Supplied
No. 128	Months	Pounds	per cent	Pounds	Pounds	Therms	Therms
	* 11	520	117	0.839	0.833	5.239	5.004
	12	538	115	0.848	0.842	5.380	5.401
	13	563	114	0.850	0.851	5.530	5.498
	14	593	112	0.850	0.853	5.730	5.767
Average		556	114	0.847	0.846	5.491	5.455
No. 125							
	* 11	492	110	0.850	0.830	5.033	4.905
	12	513	109	0.837	0.841	5.190	5.192
	13	528	108	0.843	0.851	5.300	5.379
	14	552	108	0.850	0.851	5.460	5.469
Average		524	109	0.841	0.844	5.269	5.266
No. 131							
	* 10	454	108	0.817	0.810	4.752	4.667
	11	471	106	0.823	0.830	4.880	4.905
	12	492	105	0.830	0.841	5.042	5.004
	13	519	105	0.840	0.841	5.230	5.192
Average		486	106	0.828	0.823	4.996	4.943

* Note - 20 days only.

TABLE 16

GROUP RECEIVING PROTEIN ACCORDING TO ARMSBY'S STANDARD, ENERGY 15% BELOW.

Feed Consumed Daily
and
Daily Gain in Weight
by
30 day periods.

	Prairie Hay	Corn Silage	Grain Mixture	Oil meal	Gain in Weight	
					Actual	Normal
No. 511	Pounds	Pounds	Pounds	Pounds	Pounds	Pounds
	* 3	7	1.8	1.5	1.14	None
	4	8	1.4	1.5	0.30	"
	4	8	1.8	1.4	1.90	"
	4	10	1.7	1.4	0.57	"
Total	420.	920.	183.0	159.0	96.00	"
Average	3.8	8.3	1.66	1.44	0.87	"

* Note - 20 days only.

TABLE 17

GROUP RECEIVING PROTEIN ACCORDING TO ARMSBY'S STANDARD, ENERGY 15% BELOW.

Record of Weights
and
Comparison of Nutrients Consumed with Armsby's Standard.

Average per day for 30 day periods.

	Age	Weight	Weight compared to Normal	Dig. Crude Protein		Net Energy	
				Armsby's Standard	Supplied	Armsby's Standard	Supplied
No. 511	Months	Pounds	per cent	Pounds	Pounds	Therms	Therms
	* 11	492	---	0.830	0.830	5.042	4.905
	12	512	---	0.837	0.841	5.173	5.192
	13	541	---	0.84[illegible]	0.851	5.389	5.379
	14	568	---	0.850	0.860	5.570	5.627
Average		532		0.842	0.847	5.316	5.309

* Note - 20 days only.

Group II, Receiving Protein According to the Armsby Standard, Energy 15% Below.- This group was to receive protein according to the Armsby standard and energy 15% below. Records show that the protein supply was in every case within 0.6 of one per cent of the required amount, and that the energy supplied did not vary more than 0.06 of a therm from the required amount, which is a variation of less than 1.3% .

Ayrshire heifer number 9 averaged 688 lbs. in weight for the period, and made an average daily gain of 0.97 lbs. which is a gain of 166% as compared to the normal for her age.

Holstein heifer number 339 weighed 752 lbs. for the average of the period and made an average daily gain of 1.17 lbs., which is a gain of 134% as compared to the normal.

Holstein heifer 342, with an average weight of 781 lbs. for the period, made an average daily gain of 1.10 lbs., or 152% as compared to the normal.

Holstein 346, averaging 538 lbs. in weight for the period, made an average daily gain of 1.10 lbs., which represents an increase of 95% as compared to the normal for this age. This is the only animal in group II that made less than 100% gain as compared to the normal. This animal was badly infected with lice, and it was not until these were killed that the animal made normal gains. However, the trial had been under way nearly a month before her condition was noticed.

Jersey heifer number 123, averaged 549 lbs. in weight for the period and made an average daily gain of 0.68 lbs. which represents a gain of 121% as compared to the normal.

Jersey heifer number 127 with an average weight of 531 lbs. for the period made a daily gain of 0.78 lbs. which is a gain of 107%

as compared to the normal.

Jersey heifer number 128, averaged 556 lbs. in weight for the period, and made an average daily gain of 0.90 lbs., which is a gain of 123% as compared to the normal.

Jersey heifer number 125, with an average weight of 524 lbs. for the period, made an average daily gain of 0.81 lbs., or a gain of 111% as compared to the normal for that age.

Jersey heifer number 131 averaged 486 lbs. for the period and made an average daily gain of 0.81 lbs., which represents a gain of 101% as compared to the normal. Records show that this animal received the largest cut in energy of any of the animals on experiment. The actual energy supply being 16.3% less than supplied by Armsby's standard.

Guernsey heifer number 511 averaged 532 lbs. in weight for the period, and made an average daily gain of 0.87 lbs. As stated about the Guernsey heifer in group I, although there are no normal growth figures available, it is believed that the growth represents more than a normal one.

A summary of the records for this group is given in table 18. These data show the average weight of the ten heifers to be 544 lbs., and the average daily gain as 0.92 lbs., which represents a gain of 123% as compared to the normal.

Comparison of the two Groups.- Records of feed consumption of the two groups are given in table 2 to 17 inclusive. These data show that in neither case did the protein consumed vary as much as one per cent from Armsby's standard. In Group I the energy supply was at all times within 2.1 per cent of the required amount, while in Group 2 the supply did not vary more than 1.3 per cent from

Armsby's standard -15 per cent in energy.

Records of growth of these two groups are given in table 18 and graph 1. These data show that each group consisted of 10 heifers, made up of four different breeds. Group I, when put on experiment averaged 546 lbs. in weight, at the average of 11.3 months, while Group II weighed 544 lbs. at an average of 11.7 months.

Group I made an average daily gain of 1.11 lbs. as compared to the normal of 0.82 lbs. which is a gain of 138% as compared to the normal, while Group II made an average daily gain of 0.92 lbs. as compared to the normal of 0.77 lbs. which represents a gain of 123% as compared to the normal.

TABLE 18

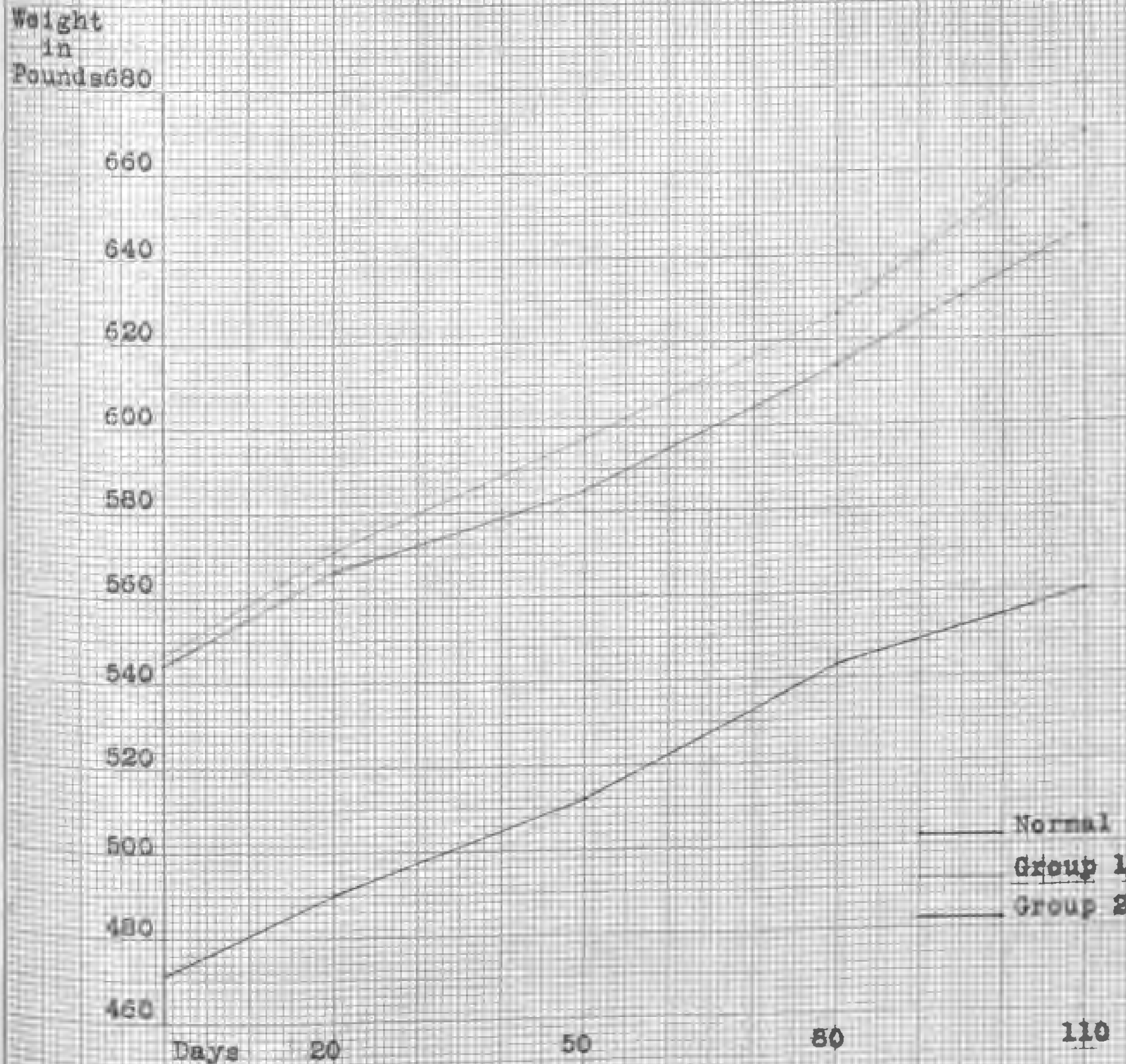
SUMMARY OF RESULTS.

Group Receiving Protein and Energy according to Armsby's Standard.
Compared to
Group Receiving Protein According to Armsby's Standard,
Energy 15% below.

No. of Animal	Age at Beginning	Ration as compared to Armsby's Standard	Weight at Beginning	Gain per Day	Normal Gain per Day	Gain as compared to Normal
	Months		Pounds	Pounds	Pounds	per cent
8	14	N	636	1.11	0.59	188.
10	13	N	590	1.27	0.77	164
341	15	N	749	0.97	0.87	111
345	8	N	542	1.55	1.11	139
347	7	N	531	1.61	1.16	139
510	12	N	490	1.04	----	---
126	11	N	502	0.97	0.73	133
129	11	N	473	1.09	0.73	149
124	12	N	534	0.82	0.64	128
130	10	N	416	0.73	0.80	91
Average	11.3	N	546	1.11	0.82	138
9	14	- 15%	630	0.97	0.59	166
339	15	- 15%	703	1.17	0.87	134
342	13	- 15%	722	1.10	0.72	152
346	7	- 15%	481	1.10	1.16	95
511	11	- 15%	480	0.87	----	---
123	14	- 15%	516	0.68	0.56	121
127	11	- 15%	489	0.78	0.73	107
128	11	- 15%	505	0.90	0.73	123
125	11	- 15%	480	0.81	0.73	111
131	10	- 15%	442	0.81	0.80	101
Average	11.7	- 15%	544	0.92	0.77	12[illegible]

GRAPH 1.

Comparison of Growth by Groups



Group 1 Receiving Protein and Energy According to Armsby's Standard

Group 2 Receiving Protein According to Armsby's Standard, Energy 15% Below.

Summary of Results.- A summary of the results of this experiment is given in tables 18 to 19 and is illustrated by graph 1. These data show that the heifers on experiment were divided as fair as possible, according age, weight, and breed, into two groups. Both groups received the same quantity of protein, and group 2 received 15 per cent less energy than did group 1, which was fed according to the Armsby standard. Group 1 made an average daily gain of 1.11 lbs., or a gain of 138% as compared to the normal, in comparison to a gain of 0.92 lbs., or 123% normal by group 2.

A study of the energy consumed by the two groups shows that, on the average, the 20 animals were underfed 8 per cent as compared to Armsby's standard. With this amount of energy the heifers made an average daily gain of 1.02 lbs., or a gain of 130% as compared to the normal.

A study of group 1 indicates clearly that, although both groups were started at a weight much greater than normal, the gain for the feeding period was in both cases greater than the normal. A further study shows that group 1 started the 110 day feeding period at an average weight of 2 lbs. greater than the average for group 2. At the end of the feeding trial we find the average weight of group 1, 23 lbs. greater than than that of group 2. This shows clearly that for the period of 110 days group 1 made an average gain of 21 lbs. greater than did group 2.

TABLE 19

RELATION OF BREED TO GAIN IN WEIGHT.

Group 1 Receiving Protein and Energy According to Armsby's Standard
Compared to
Group 2 Receiving Protein According to Armsby' Standard,
Energy 15% Below.

	Breed	No. of Animals	Gain per Day	Gain as compared to Normal
			Pounds	per cent
Group 1	Holstein	3	1.37	129
	Ayrshire	2	1.19	176
	Guernsey	1	1.04	
	Jersey	4	0.94	125
Total and Average		10	1.11	138
Group 2	Holstein	3	1.12	127
	Ayrshire	1	0.97	166
	Guernsey	1	0.87	
	Jersey	5	0.80	113
Total and Average		10	0.92	123
Average Group 1 and Group 2	Holstein	6	1.25	128
	Ayrshire	3	1.12	172
	Guernsey	2	0.96	
	Jersey	9	0.84	118
Total and Average		20	1.02	130

Relation of Breed to Gain in Weight.- Recorded results give no clear evidence of any specific breed difference in the utilization of food. However, it is a common observation that on a rather low plane of nutrition, as on poor pasture, certain breeds do better than others. It is not known whether this is due to the fact that the breed makes better use of the feed, or if breed is a better grazer.

Data taken during this investigation, having a bearing on the relation of breed to gain in weight, is given in table 19. These results were obtained from two groups of heifers of ten each, one fed protein and energy according to the Armsby standard, and the second fed protein according to the Armsby standard and energy 15 per cent below.

In comparing the average daily gains secured, the breeds rank Holsteins first, followed in order by the Ayrshires, Guernseys and Jerseys,- making a daily gain of 1.25, 1.12, 0.96 and 0.84 pounds respectively A comparison of the gain expressed in per cent as compared to the normal ranks the Ayrshire breed first, followed in order by the Holsteins and Jerseys with a gain of 172, 128 and 118 per cent respectively. No normal growth figures are available with which to compare the Guernsey breed.

These data are taken from a comparatively few animals so that age, individuality, plane of nutrition and other factors enter in for consideration. For these reasons the results lose much of their value, and should not be taken as conclusive.

TABLE 20

RELATION OF AGE
TO
GAIN IN WEIGHT.

Age at Beginning	Experimental Animals	Gain as compared to Normal
Months	Number	per cent
7	2	117
8	1	139
9	0	0
10	2	96
11	5	124
12	1	128
13	2	158
14	3	158
15	2	123

Note - Duration of trial 110 days.

Relation of Age to Gain in Weight.- While it was not the purpose of this experiment to collect data dealing with the relation of age to gain in weight, the results secured were used with the hope of throwing some light on the subject.

The maintenance requirement of young animals is naturally smaller per head than that of older animals on account of the difference in size. Whether there is a difference in the requirement of two animals of the same weight, but different ages, is not altogether clear.

As animals become larger the Armsby standard undertakes to meet the increased energy requirement. This standard may meet the conditions at one age and still be wrong at another.

Data on the subject referred to are given in table 20. These results show that the heifers at all ages, excepting two at the age of ten months, made more than normal growth. The largest average gain, 158 per cent as compared to the normal, was made by the three heifers 14 months old, while the second largest average daily gain, 139 per cent as compared to the normal was made by the heifer 8 months old, and the smallest average daily gain, 96 per cent as compared to the normal, was made by the two heifers 10 months old.

While these results appear somewhat inconsistent, it would seem that these irregularities are primarily due to individuality or factors other than age, for the data represent the results of a too limited number of animals for a work of this character. However, these results combined with the results of experiments contained in the literature reviewed would tend to show that Armsby's present standard is equally too high for all ages.

C O N C L U S I O N S .

1. Data collected show that the energy requirements as set forth in Armsby's present feeding standard for growing heifers are unnecessarily high.

2. Heifers receiving protein and energy according to the Armsby standard made gains larger than normal, or an average daily gain of 138 per cent as compared to the normal.

3. Heifers receiving protein according to the Armsby standard and energy 15 per cent below made gains greater than normal, or an average daily gain of 123 per cent as compared to the normal.

4. Results tend to show that Armsby's standard gives the proper increase in energy requirement with increasing age, but that the requirement is equally too high for all ages.

5. Data presented are too limited to warrent conclusions as to the relation of breed to energy requirement.

PLATE 1.

HEIFER 341.

Fed Protein and Energy According to Armsby's Standard.

At Close of Experiment.

Age, 19 Months

Weight, 856 lbs. (119% of Normal)

Av. Daily Gain, 0.97 lbs. (111% of Normal)

Height, 123.6 cm. (101% of Normal)

PLATE 2.

HEIFER 342.

Fed Protein According to Armsby's Standard,
Energy 15% below.

At Close of Experiment.

Age, 17 Months

Weight, 844 lbs. (127% of Normal)

Av. Daily Gain, 1.10 lbs. (152% of Normal)

Height, 122.2 cm. (101% of Normal)

PLATE 3.

HEIFER 8.

Fed Protein and Energy According to Armsby's Standard.

At Close of Experiment.

Age, 18 Months

Weight, 758 lbs. (125% of Normal)

Av. Daily Gain, 1.11 lbs. (188% of Normal)

Height, 120.4 cm. (108% of Normal)

PLATE 4.

HEIFER 9.

Fed Protein According to Armsby's Standard,
Energy 15% Below.

At Close of Experiment.

Age, 18 Months

Weight, 737 lbs. (122% of Normal)

Av. Daily Gain, 0.97 lbs. (166% of Normal)

Height, 119.2 cm. (107% of Normal)

PLATE 5.

HEIFER 510.

Fed Protein and Energy According to Armsby's Standard.

At Close of Experiment.

Age, 16 Months

Weight, 605 lbs.

Av. Daily Gain, 1.04 lbs.

Height, 112.4 cm.

PLATE 6.

HEIFER 511.

Fed Protein According to Armsby's Standard,
Energy 15% Below.

At Close of Experiment.

Age, 15 Months

Weight, 576 lbs.

Av. Daily Gain, 0.87 lbs.

Height, 116.4 cm.

PLATE 7.

HEIFER 129.

Fed Protein and Energy According to Armsby's Standard.

At Close of Experiment.

Age, 15 Months

Weight, 592 lbs. (114% of Normal)

Av. Daily Gain, 1.09 lbs. (149% of Normal)

Height, 117.1 cm. (104% of Normal)

PLATE 8.

HEIFER 128.

Fed Protein According to Armsby's Standard,
Energy 15% Below.

At Close of Experiment.

Age, 15 Months.

Weight, 604 lbs. (116% of Normal)

Av. Daily Gain, 0.90 lbs. (123% of Normal)

Height, 116.4 cm. (103% of Normal)

PLATE 9.

HEIFER 347.

Fed Protein and Energy According to Armsby's Standard.

At Close of Experiment.

Age, 11 Months

Weight, 712 lbs. (134% of Normal)

Av. Daily Gain, 1.61 lbs. (139% of Normal)

Height, 124.2 cm. (110% of Normal)

PLATE 10.

HEIFER 346.

Fed Protein According to Armsby's Standard,
Energy 15% Below.

At Close of Experiment.

Age, 11 Months

Weight, 602 lbs. (114% of Normal)

Av. Daily Gain, 1.10 lbs. (95% of Normal)

Height, 119.2 cm. (106% of Normal)

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