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 **Samuel Basherov** 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.**

O. H. Eckles
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F. B. Kingsbury

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Date July 27 1922

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 Samuel Basherov final oral examination for the degree of

Master of Science.

We recommend that the degree of

Master of Science

be conferred upon the candidate.

C. H. Eckles
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E. F. Ferrin

Date July 27 1922

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ENERGY REQUIREMENTS

FOR

THE NORMAL GROWTH OF DAIRY HEIFERS.

By

SAMUEL BASHEROV.

Submitted in Partial Fulfillment of The

Requirements For The Degree of

MASTER OF SCIENCE

in the

GRADUATE SCHOOL

of the

UNIVERSITY OF MINNESOTA.

1922.

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ACKNOWLEDGEMENT.

The writer wishes to express his sincere thanks to Dr. C.H. Eckles, Chief of the Dairy Division, University of Minnesota, for his valuable suggestions and helpful guidance throughout the entire preparation of this thesis.

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INTRODUCTION.

People whose diet includes an adequate supply of dairy products are the leaders in human progress. In localities where dairy cows are scarce, as in the Southern States, the health conditions of the people are poor, and diseases directly attributed to inadequate diet such as pellagra are common.

The dairy industry in the United States is one of the greatest assets of the nation, furnishing as it does a food product so essential to the health and progress of its people and so indispensible as a daily article of food for the children.

Furthermore, it must not be overlooked that the dairy cow is by far the most efficient producer of human food among the farm animals. In addition, dairying is a type of farming that makes for a proper balance of agriculture, which is, after all, the backbone of any nation.

Statistics show that there are about 25,000,000 cows in this country used for dairy purposes which bring an annual income to the farmers worth approximately $2,500,000,000. To replenish the worn-out cows, it requires that about 9,000,000 heifers be raised yearly, half of which come into milk for the first time.

The raising of so many animals involves a yearly expenditure of over $450,000,000. It is of great importance, therefore, that economy be practiced in the raising of these heifers, but not to the extent of sacrificing their development and future efficiency as milk producers.

There are two factors involved in the growth of young animals. One of these is what has been termed the growth impulse and depends upon the internal factor which is inherited by the animal. The other is the external factor which represents the summation of those external influences which effect growth; of the many factors which together constitute this external influence the most important is without question the food supply.

During the last few years investigators in the field of nutrition have found that an animal to make normal growth must receive in its ration proteins of proper quality and sufficient quantity, carbohydrates, fat, mineral salts, and vitamines. It has further been stated by such authorities as Hopkins and Osborne and Mendel, that according to the law of minimum, the total intake of net energy may also become the limiting factor in growth. Thus, an insufficient supply of total nutrients in the diet, may prevent the young animal from reaching normal size; whereas, feeding total energy above that necessary to make normal growth would be wasteful.

There are at present three different feeding standards that give the nutrients required for the growth of dairy cattle. The requirements as set forth in them are, however, not based on investigations involving young dairy heifers, but are estimates from data obtained on older animals. Of these standards, Armsby's is probably the most accurate. Recent investigations have revealed that though Armsby's standard may be nearly correct in its estimates for the nutrient requirements of young calves, it is unnecessarily high for older heifers.

The thesis presents additional data taken on this subject

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with such deductions as seem justified. It is evident that a work so limited in scope and time as a thesis cannot solve so large a problem. It is, however, hoped that the data presented will contribute to the ultimate solution of the energy requirements for the normal growth of dairy heifers.

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REVIEW OF LITERATURE.

A review of the literature on this subject reveals the fact that there is little material available that has a direct bearing upon the energy requirements of dairy heifers for normal growth. One is, however, overwhelmed by the great quantity of material there is on the general problem of nutrition of animals. In spite of this great accumulation of knowledge on nutrition, the leading authorities in this branch of science agree that nearly all of the fundamental facts concerning nutrition still remain to be determined.

Since this thesis deals with young animals it seems appropriate to include here a discussion of the theories of growth as well as some of the other factors, besides energy, that play such an important role in the nutrition of growing animals.

Growth.

Definition of Growth. Growth like most other natural phenomena is very difficult to define. Many of the ablest investigators in physiology, nutrition, and other kindred subjects, have studied growth and some have attempted to define it. An examination of the various definitions reveals the fact that there are no two of them exactly alike. The most general definition of growth seems to be "increase in volume" or "increase in size".

Morgan (1) in discussing growth states "that the most general definition of organic growth is that of increase in volume.

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Sachs has, however, pointed out that an increase in volume alone does not necessarily mean growth, because it may be due simply to swelling, as when a piece of dead wood imbibes water and becomes larger. Sachs defines growth as an 'increase in volume accompanied by a change of form.' Yet a change of form is not always apparent when we have reason to think that growth has really occurred. 'If however we include in our definition of growth the idea of an increase in volume of the living material we arrive at a more satisfactory definition.'"

Growth as a Function of Cell Tissues. When we inquire as to how an animal or plant grows we find more definite and comprehensive views: According to Mumford (2) "growth occurs as a result of continued cell division rather than by any material increase in the size of the existing cells." Bigelow (3) states "that the growth of an organism is the sum of the growths of its tissues, and the growth of its tissues depends on that of the cells: hence, growth entirely rests upon first, the increase in size of single cells and second, the multiplication of cells." Armsby (4) expresses a similar view when he states that "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." Mendel (5) quotes the following from Lee: "All growth 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 two being the most important."

The Laws of Mammalian Growth. Extensive investigations of the laws of growth have been made by Minot (6). His experiments

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were conducted mainly on guinea-pigs, but include also rabbits and chickens. The results obtained showed that in the period from the ninth to the fifteenth day the young embryo rabbit adds on an average 704 per cent to its weight daily and that in the period from the fifteenth to the twentieth day the average daily addition is only 212 per cent. Minot estimates that over 98 per cent of the original power of growth of the rabbit or the chick has been lost at the time of birth or hatching and that a similar fact is equally true of man. Other investigators have shown that a retardation in the relative rate of growth begins long before birth, probably at the time of histological differentiation. The rate of growth of the human embryo during the first month, assuming the ovum to weigh 0.000,004 grams, is estimated by Jackson (7) to be between one million and fifty million per cent. From this it declines at first very rapidly and then more slowly to less than twenty per cent during the ninth month. It is further shown that the constant loss in the rate of gain is a fundamental law of growth.

Growth Under Adverse Conditions. Waters (8) kept 15 steers, varying from show animals to those in ordinary farm condition, for a long period on a ration sufficient for maintenance only. In each case there was an increase in the height of the animal at the withers, the length of head, the depth of chest, denoting the growth of the skeleton. Arons (9) working with dogs under similar conditions concludes that the "growth tendency is more noticeable in the skeleton than in the other parts of the body."

Waters (10) has further shown that a young animal whose growth has been checked by underfeeding for as long a period as a year, will recover to a surprising extent when placed on liberal feed. Osborne and Mendell (11) have also demonstrated that rats whose growth has been checked by insufficient food will resume growth at an age beyond the end of their normal growing period.

From his experiments Waters (12) concludes that the young animal may advance to normal size by any or all of the following ways:

1. By continually growing from birth to maturity.
2. By storing fat in a period of abundance of food supply to assist in tiding over a limited period of sparse food supply without serious interruption of growth.
3. By prolonging the growth period.
4. By increase in the rate of growth during a period of liberal feeding followed by a period of low nourishment and low gain.

Results of investigations somewhat contrary to the above findings and conclusions on the effect of stunting young animals are given by McCollum (13). He states that "when the protein content of the ration is low young rats remain approximately normal in form, or at least they remain long and lithe. When the inorganic content of a ration is faulty, on the other hand, they develope a short and stocky form. In the former case they respond to a better protein supply and look approximately normal but when deformed by lack of Ca they never assume the normal form as the result of correction of the diet."

So far nothing has been said of the initiation of growth. What is the underlying cause of growth? Those who have studied

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this question have to admit that they know practically nothing as to what takes place in protoplasm during growth and very little regarding the causes which incite or inhibit it. Unquestionably the external factor, food and environment, may in a sense be regarded as a supreme cause of growth. But of what has been referred to as the "internal factor", the "growth impulse" - the factor which is hereditary in its nature and sets to growth the limit which nutrition cannot alter, nothing more can be said. It may be that the capacity to grow is dependent upon the action of "hormones", products of internal secretions and cellular metabolism (14). If so, it would seem in place to proceed with a discussion of the ductless glands with their internal secretions, and especially in so far as they have a bearing on growth.

Internal Secretions of Ductless Glands.

According to Howell (15) the term "internal secretion" is used to designate those secretions of glandular tissues which, instead of being carried off to the exterior by duct, are eliminated in the blood and lymph. Vincent (16) states that the process of "internal secretion" consists in the preparation and setting free of certain substances of physiological utility by certain cells of the glandular type; the substances set free are not passed out to a free surface, but into the blood stream. Starling (17) looks upon "internal secretions" as chemical messengers and designates them as "hormones" which means to cause to activity. Their function being to arouse to activity certain organs in the body. Mathews (18) has given the name of "cryptorrhetic organs" to the ductless glands of internal secretions. He states "they are the

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tissues of hidden flowing". Among these organs only those that have a special influence on metabolism and growth will be considered; namely, the hypophysis, parathyroids, thyroid, suprarenal bodies, sexual glands, thymus, pineal body, and the pancreas.

The Hypohysis. In human beings the hypophysis is about as large as a pea and is situated at the base of the brain with the optic chiasma just in front of it (19). The organ as a whole plays a very important part in regulating the life processes of an individual, but the anterior and posterior parts have different functions.

Cushing (20), working with dogs, showed that definite metabolic changes occur after the partial extirpation of the anterior lobe of the pituitary in dogs, particularly in young dogs. There was a great deposition öf fat in the body everywhere. In young dogs there was a persistence of the thymus and rudimentary condition of the sexual organs, a persistant infantilism.

Aschner (21) also working with dogs, found that removal of the gland from adult dogs was not followed by any marked disturbance of health. However, there was a decided tendency to fatness. Neither did he find any marked atrophy of the sexual glands. Extirpation of the organ in young dogs 6 to 10 weeks old was followed by a great cessation of growth. The dogs do not grow except in fat; they keep their puppy hair and milk teeth, the genital organs remain in infantile condition. The thymus persists much longer and the intelligence remains submormal. Schaefer (22) fed young rats extracts of the anterior lobe and obtained a slight increase in growth as compared to the control animals.

The posterior lobe is quite distinct in its physiological

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function. No disturbance of growth takes place when it alone is removed. (23).

According to Howell (24) "The differentiation in function between the two parts cannot be made completely, but it seems that the anterior lobe furnishes a secretion that stimulates the growth of the skeleton, and possibly the connective tissue 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 more hormones that have a stimulating effect upon several processes - the tone of plain muscle, the secretary action of several glands, the process of glycogenolysis, and a regulating influence upon the normal development of the reproductive organs."

<u>The Thyroid Gland and the Parathyroids.</u> The thyroid gland consists of two oval bodies located on each side of the trachea, in many animals they are joined across the trachea by an isthmus. The parathyroids are small bodies, four in number, and are situated on the border of the thyroid gland and some are actually embedded in its substance (25).

In 1856, Schiff (26) showed that removal of the thyroids in dogs caused the animal to die in from one to four weeks. It later became known that atrophy of the thyroids in the young is responsible for the condition of arrested growth and deficient mental development called cretinism, and in an adult the same cause gives rise to myxedema, characterized by distressing mental deterioration, an endematous condition of the skin, loss of hair, etc. Schiff further proved that grafting pieces of thyroid, feeding it, or injecting extract under the skin cured the above named

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conditions. Kendall (27) reports a case of a ten-year old girl that suffered from thyroid deficiency and was undersized. She was given 4 mgs. of thyroxin daily for 6 months, during which time she grew 4 inches. She not only grew taller, but her skin became soft and moist, and her hair softer and much longer. Her mentality was wonderfully improved.

Mathews (28) states that when Morel removed the parathyroids from dogs, there followed many symptoms of a nervous character and the animals died within 10 days. He further states that one of the results of the extirpation of these glands is that neither bones nor teeth calcify properly, so that in rats conditions analogous to rachitis and osteomalacia are produced. It is interesting to note in this connection that according to Cushing (29) the hypophysis also is in some way linked up with the normal utilization of Ca.

The nature of the thyroid hormone has been studied with success. Kendall (30) has isolated from the gland a compound containing iodine which possesses the physiological properties of thyroid extract. He gave it the formula of $C_{11} H_{10} O_3 NI_3$ and called it thyroxin.

In summing up, it may therefore be stated that the removal or diminution in function of the thyroid in the adult causes a condition of malnutrition, which leads to perverted metabolism such as myxedema in man. Removal of the glands or suppression of their function in early life is also followed by perverted metabolism which exhibits itself in retarded growth of the skeleton, and in the brain, as in the case of cretinism. The removal of the parathyroids in dogs is followed quickly by death.

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It is generally believed that the symptoms of exopthalimic goiter owe their origin, in part at least, to hyperthyroidism.

The Suprarenal Bodies. The suprarenal capsules in mammals are two small masses lying on the upper side of the kidneys (31). According to the citations of authorities, Brown-Sequard was the first to show that the extirpation of the adrenal bodies is rapidly followed by death. These results have been confirmed by later investigators. It was found that in Addison's disease the autopsy constantly showed lesions of the supraprenal capsules. These lesions are generally tubercular in nature.

According to Howell (32) "the normal functional value of the medullary tissue and the other chromaffin tissues consists, so far as we know, in the production of secretion of epinephrin."

Cannon-Haskin (33) indicated that the venous blood flowing from the adrenals contains epinephrin. This substance according to Aldrich (34) has the chemical formula of $C_9 H_{13} NO_3$. Its function appears to be to reinforce the action of the sympathetic nervous system, thus increasing vasomotor tone, sympathetic tone, the tone of the digestive system, the bladder and uterus, and all other structures innervated by the sympathetic. When adrenalin is injected intravenously it causes glycosuria.

According to Cannon (35) emotional excitement causes an increased secretion of epinephrin which gives a more rapid heartbeat, a greater flow of blood, stimulates the nervous system and increases the output of sugar from the liver.

The functions of the cortex is not as yet understood. It has been suggested that the adrenoline is elaborated here and stored in the medulla but nothing definite is as yet known.

Vincent (36) states "our knowledge regarding the function of the cortex are less complete but highly interesting. In some of the fishes this portion of the gland is anatomically distinct from the medullary portion. Its extirpation in these animals is followed by a condition of progressive muscular weakness ending in death. This result indicates that the cortex has some function essential to life and it is probable that this function is mediated thru an internal secretion containing a hormone different from epinephrin."

<u>The Sexual Glands</u>. Mathews (37) states, "that the ovaries and testes have a very marked effect on the growth and metabolism has long been known". Castration has been practiced for a long time for the purpose of modifying the body form and temperament. The reproductive organs give off (38) either from the germ or interstitial cells substances which, circulating in the blood, change the growth of the horns and bones in cattle and bring out the so-called secondary sexual characters. The nature of the internal secretions of these organs is, however, unknown (39).

Howell (40) cites experiments conducted by Steinach "in which young males (rats and guinea pigs) were first castrated and then had transplanted under the skin the ovary from a female of the same species. In such animals the secondary male characteristics do not develope, his genital organs remain infantile; he exhibits on the contrary the female characteristics, as shown by his size, the character of the hair, and especially by the development of the mammae and nipples". It would follow from these experiments that the internal secretions of the interstitial cells

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in the ovary and the testes has each its specific influence in guiding the development of sexual characters.

Schaefer (41) found that castration of young animals prevents the development of male characteristics and causes the limb bones to become longer. He further states that most of the ductless glands are in some way affected, the growth of the thyroid being diminished, that of the suprarenal cortex, pituitary and thymus, increased. If castration is performed in mature animals the main effects are upon the metabolism and a special tendency to increased formation of fat. The results obtained from removing both ovaries are externally not so striking as with the similar operation of the male sex. Metabolism is affected mainly as in males, in the direction towards adiposity. The internal secretions of the different glands seem to be effected in the same way as in the male.

<u>The Thymus</u>. According to Schafer (42)"the functions of the thymus are more obscure than most of the endocrine organs." Most authorities seem to agree that the physiology of the thymus gland is still unknown, except perhaps that it is concerned in some way with growth. It is thought that the gland furnishes an internal secretion which influences in some way body metabolism at least in early life. Contrary to former beliefs, the thymus retains its size until puberty. After that it generally undergoes atrophy or involution, but does not entirely disappear.

Injection of extracts of the gland, or the feeding of it seems to have no specific effect. Gudernatsch (43) fed tadpoles with thymus and found that they were prevented from undergoing metamorphosis, although they increased greatly in size. Howell (44) citing Basch states that removal of the thymus in young dogs is said to cause a retarded growth of the body tissue and produce a condition resembling rickets.

According to Marshall (45) there is a reciprocal relation between the thymus and the testes, each checking the growth of the other. This conclusion is based on a series of observations on cattle and guinea-pigs. It would thus seem that the thymus is in some way connected up with growth and its presence seems to be of special importance during the prepubetal stage.

<u>The Pineal Gland</u>. This small body (46) is a rudimentary organ in the brain corresponding in a general way on the upper surface to the hypophysis on the lower. Little is as yet known about the function of this organ, but it appears to be closely related to the sexual organs.

According to Howell (47) this organ reaches its fullest development in man about the seventh year. After this period and particularly after puberty it undergoes a process of involution during which the glandular structure disappears and is replaced by fibrous tissue.

McCord (48) states that tumors involving the pineal body and causing a deminished activity of the gland is followed by an accelerated development of the sexual organs, with an attending mental precosity and an increased growth of skeleton. This would lead to the conclusion that the hormone produced by the pineal body inhibits or regulates growth and particularly restrains the development of the reproductive organs. He also fed pineal tissue to guinea-pigs, puppies, dogs, and chicks, and found that it stimulates rapid growth of body, but not beyond normal size. On the other

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hand, Cushing (49) states "that a number of successful canine pineal extirpations by Dandy led to no recognizable post operative symptoms" and concludes from this that "it would thus seem that no physiological significance can be attributed to this structure."

The Pancreas. In 1889, von Mehring and Minkovski found that complete removal of the pancreas brings on a condition of glycosuria known as pancreatic diabetes (50). Acetone and B-oxy-butyric acid are also present in the urine, and as in diabetes mellitus in man, the animal shows polyuria and abnormal thirst and hunger. These symptoms are followed by muscular weakness, emaciation and in a few weeks by death.

It is believed (51) that the pancreas forms an internal secretion which is given off to the blood which is supposed to play an important part in the metabolism of carbohydrates.

According to some investigators (52) the hormones furnished by the pancreas plays an important part in the process known as glycolysis, that is to say a series of changes by which sugar is broken down and finally oxidized to H_2O and CO_2. Other observers hold that the pancreatic secretion normally regulates the output of the sugar from the liver and other tissues. In its absence this output is increased and raises the sugar content of the blood to such an extent as to cause glycosuria.

In closing the discussion on the internal secretions it might be well to point out their interrelation to each other.

According to Baylis (53) who states that "various statements have been made as to the mutual relation of these organs, who have based elaborate theories on very slender evidence."

Elliot (54) points out some of the following common

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features among these organs which suggest a common bond:

(1) Carbohydrate metabolism is influenced not only by the pancreas, but also by the thyroid in superactivity, in acromegaly, and by injection of adrenoline.

(2) Growth is effected by the testes and the cortex of the suprarenals, arrested by absence of the thyroid.

(3) Nervous implications are less obvious.

(4) The pituitary becomes hypertrophied when the thyroid is removed. Acromegaly may lead to enlargement of the thyroid.

(5) Gaskell, on morpholigical grounds, classified together the suprarenal cortex, the pituitary, and the thyroid as being modified from the coxal glands.

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Nutrition and Growth.

We now come to the study of the second factor which determines growth and which has been designated as the external factor, and represents the summation of those external influences which effect growth. Of the many factors which together constitute this external influence the most important is without question the food supply. It will, therefore, be realized what fundamental importance is to be attached to a full understanding of the food requirements of the animal body during the growth period, since these represent the chief factors which are under our control.

Requirements for a Complete Ration. Our knowledge of nutrition has progressed with the development of the science of chemistry. Chemical science gave us the clue to an understanding of the nature of food-stuffs and the changes which take place in digestion, as well as an appreciation of some of the secrets of the metabolic processes which take place within the tissues of the body.

Since protein, carbohydrates, fat, and mineral matter came to be regarded as the essential constituents of the normal diet, it early became the principal activity of investigators of nutrition problems to analyze foods of every sort by chemical methods in order to determine their content of what were supposed to be the only essential food requirements.

Within the last decade, however, due to the feeding of purified food nutrients to laboratory animals, the subsequent discovery of vitamines and the part they play in the proper nutrition of growing animals, a great impulse has been given to the study of food-stuffs from the physiological standpoint that they have upon animals and much valuable information has been obtained. Such nutrition authorities as Hopkins, Osborne and Mendel, McCollum, and many others equally as well known, agree in their findings that a young animal to make proper growth and maintain a good state of health requires in his ration proteins of proper quality as well as quantity, carbohydrates, fats, mineral matter, and at least two and possibly three growth complexes. In addition to the nutrient requirements experience has shown that a ration for the dairy heifer must be palatable and bulky to enable her to consume large quantities of roughage in order to extend and develope her digestive capacity for consuming large quantities of feed which ability she can later utilize in the economic production of milk and butter fat.

Proteins. The proteins (55) are organic substances found in nature in living matter, or associated with it and always produced by it. They consist of C. H. N. O. generally, but always some S. and sometimes they contain P. The protein molecule is very complex. Fischer (56), Dekin (57), Osborne (58), Kassel (59), and others, have shown that the protein molecule is very complex, has a high molecular weight and is composed of Amino acids. So far the chemical analysis of proteins has shown that there are about twenty of these amino acids, and that proteins differ in the proportions and number of amino acids their molecules contain. A "completeprotein" is one which on hydrolysis yields all of the amino acids now known; an "incompleteprotein" is one in which some of the amino acids are missing.

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The following is a classification of the proteins as adopted by the American Physiological Society and the American Society of Biological Chemists (60):

Simple Proteins	Conjugated Proteins
1. Albumin	1. Nucleoproteins
2. Globulins	2. Glucoproteins
3. Glutelins	3. Phosphoproteins
4. Alcohol-Soluble Proteins	4. Hemoglobins
5. Albuminoids	5. Lecithoproteins
6. Histones	
7. Protamines	

Derived Proteins

A. Primary Protein Derivatives	B. Secondary Protein Derivatives
1. Proteans	1. Proteoses
2. Metaproteins	2. Peptones
3. Coagulated Proteins	3. Peptides.

The Importance of Proteins. The proteins play a very important part in the process and economy of animal nutrition. According to Jordan (61) this is true for the following reasons:

1. "The basic substance of the cell is protoplasm, a complex nitrogenous body which Huxley called'the physical basis of life', Around this primal substance seem to center all vital activities, especially the formation of the new materials of the inorganic world into the organized structure of life."

2. "The nitrogenous compounds are structurally essential to the growth and animal tissues and the formation of milk."

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Protein as Tissue Formers. (62) While there are at present many unsolved problems relative to the nutrition of proteins there is no reasonable doubt that the vegetable proteins are the primary and main source of all similar substances in the animal body. From the proteins are formed the muscles, the connective tissues, the skin, the hair, horn, and hoof and for the major part of the tissues of the secretion and excretion organs; in short they are the source of a large proportion of the working parts of the animal body. The nitrogen tissues are those that largely determine the vigor and quality of any animal and as these are formed rapidly in the early stages of growth, a normal and unrestricted development demands an abundant supply of protein food (63).

Lusk (64) and his pupils have demonstrated that at least some of the amino acids can be converted into sugars. They obtained their results by feeding various amino acids to dogs that were rendered diabetic with phlorphizin and found that some of the amino acids yielded sugar, whereas others failed to do so.

Armsby (65) states that proteins give a good example of the dual function of feeds acting as "energy carriers" and as "building material". It is therefore evident that proteins or their cleavage products not only build and repair tissues in the animal body, but in case of surplus are converted by the animal body into energy.

Protein Metabolism. The first clearly defined theory on protein metabolism was stated by Liebig (66) who held that protein material undergoes little or no chemical changes previous to its introduction into the blood stream and its assimilation of the tissues. He presumed that digestion is merely a process whereby

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food becomes changed to a soluble condition and thus becomes capable of absorption.

Recent investigations by Van Slike (67), Abel (68) and others have disproved this theory and have established the fact that when proteins are digested they yield amino acids. It is supposed that the individual amino acids are used for the resynthesis of the various proteins in the body. There are some investigators who think that the proteins used for maintenance may not be completely resynthesized. McCollum (69) states that "the repair processes are shown to be of a different character from the process of growth" and that it is probable "the processes of cellular catabolism and repair do not involve the destruction and resynthesis of the entire protein molecule."

Biological Value of Different Proteins for Maintenance and Growth. One of the most valuable investigations in the field of nutrition of recent years has been to determine the physiological value of the different proteins. It was generally accepted several years ago that all proteins were about equally alike, therefore of approximately equal value independent of their source.

The difference for this biologic difference in proteins lies in the amino acid content as has been shown by experiments with growing animals.

Voit and Munk (70) were the first to show that gelatin could not support nitrogen equilibrium. Escher (71) demonstrated that the addition of tyrosine to gelatin aided in establishing nitrogen equilibrium. Wilcock and Hopkins (72) fed young mice a diet in which casein was the sole nitrogenous constituent and obtained good growth. When zein, the principal protein of corn, replaced casein in the diet, the mice declined and died in about 17 days. The addition of tyrosin, which zein contains in sufficient amounts, had no effect upon the length of life. When, however, tryptohane which as well as lysin and glycocoll is absent from the zein molecule was added to the diet, the animals lived 32 days.

Osborne and Mendel (73) have maintained rats at an almost constant body weight for 182 days on a diet containing zein as the main source of protein with the addition of tryptophane. Since zein is also deficient in lysin, upon the addition of the latter, normal growth was obtained.

McCollum (74) fed pigs on a ration in which zein was the sole nitrogenous constituent and was able to maintain their weight for only three weeks.

Similar feeding experiments have been conducted using gliadin, one of the principal proteins derived from wheat. Thus Osborne and Mendel (75) fed gliadin as the only protein in a diet and found that mature rats may be maintained for long periods of time, but young rats fail to grow. The addition of lysin to this diet enabled the young rats to make normal growth. These investigators (76) further sought to confirm their results by feeding chicks. Two groups of chicks were fed, one group received corn gluten as its source of protein; a second group received corn gluten plus lactalbumin, a protein yielding about 10 per cent of lysin. The chicks of the first group were stunted, those of the second group grew well.

Buckner, Nallow and Kastle (77) fed young chicks grain mixtures of high and low lysin content and obtained results similar to those of Osborne and Mendel. From their experiments

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the latter conclude that "tryptophane and tyrosine are necessary for maintenance and lysin for the growth of animals."

McCollum (78) fed pigs proteins from different sources to determine the per cent of the protein that was retained by the body for building purposes. The following table gives a summary of his results:

Source of Protein	Per Cent Utilized
Oil meal proteins	16 - 17
Wheat proteins	20
Corn	24
Oats	25
Wheat germ	40
Casein	45
Skimmilk	63
Corn proteins 90%, Oil Meal proteins 10%	31
Corn proteins 75%, Oil meal proteins 25%	37
Corn proteins 60%, Oil meal proteins 40%	32

This table illustrates that the proteins of cereal grains are poor. The milk proteins are especially good as are those of the germs of the different grains. In commenting upon the low value of the oil meal proteins, he states that it is not due entirely to their poor chemical makeup, but to the "slimy carbohydrate in the oil meal that it absorbs water from the digestive tract and does not permit the animal to absorb the digestive products as efficiently as is desirable." The most interesting observation to be made, however, is the supplementing power of the proteins of oil meal for those of the corn kernel. Whereas corn proteins alone are used to the extent of 24 per cent and those of oil meal to 17 per cent, the mixture of the two is utilized to the extent of 37 per cent.

In experiments conducted in 1916, McCollum, Simmonds and Pitz (79) question as to whether lysin is the limiting amino acid in the protein of wheat, maize and oats. They have conducted feeding experiments on rats and found that (1) zein supplements the proteins of the oat kernel in a very efficient manner although it lacks tryptophane and lysin and is one of the poorest of the proteins in cystine; (2) the addition of wheat gluten to either the wheat or maize kernel proteins supplement them so as to improve growth; (3) gelatin chemically supplements the protein mixture of both the wheat kernel and the oat kernel respectively. They further state: "The results of feeding maize proteins with wheat gluten are of particular interest, however, because of their prominent effect in promoting growth despite the relatively low lysin content of both the wheat and the maize proteins. Gelatin with its high lysin content does not improve the proteins of the maize kernel." Hogan (80) also found, in his experiment with rats, that tryptophane is the first limiting factor in the proteins of the corn kernel and then lysin.

From his experiments on rats McKay (81) makes a general conclusion "that the legumes as a source of protein are superior to most of the cereals." McCollum (82) challenges this view and states "so far as chemical methods have been able to show the proteins of the bean and pea contain all the known amino acids necessary for nutrition and in no unsymmetrical distribution as in

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the case of wheat and maize proteins, yet the legume proteins have only half the value of those of the wheat and maize." He further states that "pea and bean proteins possess about the same biological value when fed alone, but the fact that the value of the bean proteins are enhanced by oat proteins, whereas the pea proteins are not, shows that the essential amino acid which forms the limiting factor is not the same in these two legume seeds. He also found that cottonseed proteins are of relatively good quality for maintenance purposes, whereas alfalfa leaves fed as a sole source of proteins showed no superiority to seed proteins.

These contradictory results would lead us to the conclusion that not too much faith is to be placed upon a chemical analysis of a food as to its indication of the value of the proteins in animal nutrition.

In 1921 a series of five papers was published in the Journal of Biological Chemistry by McCollum, Simmonds and Parsons on the supplementary values in foods. In the introductory remarks they state as follows: (83) "The interpretation of results is based upon more careful observations than have hitherto been described in any similar studies. They include not only the rate and extent of growth, the fertility, and success in rearing young, but also the period of life up to and including the onset of old age in its characteristic changes."

In the first paper the biological value of proteins in animal tissues were compared using the kidney, liver, and muscles as a source of protein at planes so as to introduce 9 per cent of the mixture. The results obtained showed that the rats produced growth scarcely superior to those of certain cereals, especially

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wheat. Here then is an instance of proteins that are "complete" but their transformation into body proteins cannot be effectively accomplished.

In the second paper McCollum and his co-workers (84) studied the supplementary value in a ration between animal tissues and cereals and legume seeds. The results of these experiments may be summed up as follows:

(1) The proteins of animal tissues are remarkably effective as supplements for the proteins of cereals.

(2) The pea, navy bean or soy bean were benefited by the addition of animal proteins but these combinations were very much inferior to similar combinations of the cereal grains as a source of proteins.

In the third paper (85) the supplementary dietary rations between the proteins of the cereal grains and the potato were compared. The results obtained show that the potato proteins tend in some degree to enhance the biological value of the proteins of cereals and legume seeds, but not to as great an extent as do proteins of animal tissues and milk.

The fourth paper (86) compares the supplementary relations of cereal grains with cereal grains; legume seeds with legume seeds; and cereal grains with legume seeds with respect to improvement in the quality of their proteins. The results of these experiments brought out the following facts:

(1) That protein mixtures derived from navy, soy beans or peas are little, if any, better than the proteins of the individual seeds.

(2) Two cereal grains when combined fail to form a protein

mixture which is markedly superior to the same amount of protein from a single grain for the nutrition of the rat.

(3) In certain instances the improvement in the quality of the proteins is decidedly great when a cereal grain is supplemented with a legume seed, as wheat and navy bean, and wheat and peas.

In the fifth paper (87) the supplementary relations of the proteins of milk for those of cereals, and of milk for those of legume seeds are compared. The results of these experiments show that animal tissues are superior to milk for the specific purpose of making good the deficiencies of the proteins of the seed and tuber, barley, peas, soy bean, rye, maize, navy bean, wheat, potato, and rolled oats. The authors point out, however, that milk is an effective supplement for those vegetable foods with respect to other factors as well as proteins. This is especially true of Ca and fat-soluble A.

To prevent a misinterpretation of these experiments, the authors make the following final statement: "It should be born in mind that the muscle tissue supplements seeds, tubers, etc., only with respect to the protein factor and that other deficiencies of even greater importance for the well-being of the body are always met with in that group of vegetable foods which are functionally storage tissues of plants; viz., seeds, tubers, and roots."

Such work as is being done by McCollum and his co-workers in determining the biological value of proteins in different foods has just been begun and promises to give some of the most valuable information that has yet been obtained in the field of protein nutrition. The future will probably see experiments of similar nature conducted with our domestic animals.

Energy.

The fuel value (88) of any feeding stuff for the animal depends upon the amount of energy it will furnish when burned in a calorimeter. This does not, however, measure its nutritive value to the animal. This is true because first, a part of the food consumed passes thru the body undigested; second, some of the carbohydrates are fermented in the intestine and paunch and gasses are evolved which are lost to the body as fuel; and third, when the proteins are broken down urea is formed which is excreted thru the kidneys. The fuel value of any food which remains after deducting these three losses represents the available energy of the food. This portion the animal can use for body purposes. But a part of this available energy the animal must use up in digestion, mastication and assimilation - the remainder is what is known as "net energy". The net energy is utilized by the animal first of all for the running of its own machinery, the heart, lungs, and other internal organs, and in case of surplus after satisfying the requirements for mere body maintenance, such surplus may be used for production of growth, fat, milk, wool or performing external work.

The net energy of feeding stuffs for animals has been determined by Armsby (89), Kellner (90) and for man by Atwater (91).

<u>The Sources of Energy</u>. The nutrients of the food that furnish energy by being consumed by an animal are proteins, carbohydrates and fat. According to Armsby (92), Jordan (93) and others, the proteins have two functions in the body. They are "tissue builders" and "serve as carriers of energy".

Howell (94) gives the following brief summary of the functions of carbohydrates and fat in the animal body:

Carbohydrates:-

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

(2) The oxidation of the sugars furnishes an important part of the constant supply of heat needed by the body.

(3) The oxidation of the sugars protects the protein of the body. An animal fed on carbohydrates alone would starve to death. Within certain limits, however, the carbohydrates are protein sparers.

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

(5) To some extent the carbohydrates may be utilized in constructive processes as in the case of the formation of nucleic acid in the body, also the lactose found in milk is a secretion of the mammary gland.

Fats:-

(1) It may be oxidized with formation of heat energy.

(2) It may be stored in the tissues as part of the body fat.

(3) It may be synthesized with other body substances to form some more complex constituent of the body, such as lecithin.

(4) According to some authors, it may serve under certain conditions as a source of sugar.

The final fate of the fat in the body is, however, to be oxidized to water and CO_2.

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<u>The Physiological Value of Fats and Carbohydrates</u>: Mathews (95) in appraising the physiological value of fats makes the following comments: "Fats are of use to the body in several ways. Being poor heat conductors, a layer of fat beneath the skin, helps to conserve the bodily heat; by their physical properties they contribute to the physical constitution of protoplasm; and finally they are heat producing foods par excellence."

Armsby (96) points out that in the case of fats the energy bearing function is the predominant and obvious one, "and that the fats and closely related bodies are important and apparently essential constituents of protoplasm and that lecithin stimulates growth."

Mendel (97) states that "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." This would appear like an exaggerated claim for the value of carbohydrates to the animal body when it is well known that the main diet of the Esquimaux consists of protein and fat and that carniverous animals, after they have passed the age of suckling, develope into strong, healthy and magnificent animals on a diet that is practically free of carbohydrates.

<u>The Energy Values for Growth</u>. According to Armsby (98) the energy values for growth are entirely analogous to that of net energy values for maintenance or for fattening. It is, however, a familiar fact that the young animal gains in weight relatively much faster than when more mature. This has naturally led to the general impression that young animals utilize their feed better

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than older one, i.e., "that the net energy value of a feeding stuff for growth is greater than for maintenance and for fattening." Armsby points out that "the difference is due to the fact that the gain in weight in a young animal is of a different nature containing more water and protein and less fat, and, therefore, less energy, whereas on the other hand the results show a greater rate of growth as regards both protein and energy." He further points out that this difference in gain is due not to the higher percentage utilization on the part of the younger animal, "but to a relatively greater consumption of feed of relatively high net energy values."

In this connection it is interesting to note that Waters (99) has found the growth impulse to be so strong in young animals that it may take precedence even over the demand of maintenance, and that an animal may even maintain its weight and continue to increase in size of skeleton for a considerable time on a sub-maintenance ration.

According to Matthews (100) "growth requires energy, first, to supply the heat necessary to keep the temperature of the body high enough to permit the chemical processes to occur with sufficient speed and to keep the protoplasm in the necessary condition of viscosity; second, to furnish the energy which is transformed in doing external and internal work, for energy is consumed in moving the blood, in secreting urine as well as in all the body movements; and third, to furnish the energy used in the synthesis of specific materials in the body, for not all the chemical transformations in the body are exothermic decompositions; there are also, synthetic, reducing, endothermic reactions by which some heat is rendered latent and in virtue of which the specific materials of the body are produced."

Mineral Matter.

Howell (101) states that the ash of animal tissues consists of chlorids, phosphates, sulphates, carbonates, flourids, or silicates of K, Na, Mg, and Fe. Iodin is found also, especially in the thyroid tissues. In the liquids of the body the main salts are NaCl, Na CO_3, Na_3 PO_4, KCl, and Ca Cl_2 or Ca_2 $(PO_4)_3$.

Henry and Morrison (102) observe that an animal fed on a ration devoid of mineral matter will perish sooner than when no food is given at all.

In McCollum's estimation (103) "there is no subject relating to agriculture regarding which there is greater need for definite and specific information than that relating to the influence of the composition and the amount of the inorganic content of the diet on growth and reproduction."

Forbes (104) who has made an extensive study of the role the minerals play in metabolism briefly sums up their functions 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 stimulation."

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

"They compose the central agency for the maintenance of neutrality in the blood."

"They enter into the composition of every living cell."

"They compose supporting structures."

"They assist in the combination of digestive processes."

"They activate enzymes and thru their control of the chemical reactions 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 effects on osmotic pressure they govern the movement of liquids, and maintain the proper liquid contents of the tissues."

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

"Thru their control of the inbibition of water by the colloids they govern absoprtion and secretion."

"Thru their control of the affinity of the blood for gasses they govern respiration."

"Finally they control the state of solution, precipitation, association, and ionization of the colloids which compose living cells."

<u>The Supply of Mineral Matter</u>. It was generally held that our feeding stuffs contain sufficient mineral matter. Investigations have shown that laying hens are benefited by an extra supply of mineral matter especially Ca in the form of shells.

Forbes (105) has demonstrated that cows in full milk

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have a negative balance of Ca, K, and P. He further showed that Ca and Mg are independent as to their retention in the body, while P was sometimes retained during periods in which both Ca and Mg were lost.

Hart, McCollum and Humphrey (106) fed a cow on a ration deficient in Ca for 3.5 months and found that during that time she gave off 5.5 pounds more of Ca in her milk and excrement than was supplied in the food. Thereby demonstrating that an animal is capable of drawing upon the mineral matter stored up in the body to supply the deficiences in the ration. It is, of course, understood that this can be done for a short time only.

Mineral Matter Required for Growth. The effect of lack of mineral matter on growing animals has been demonstrated by a number of investigators. Osborne and Mendel (107) fed rats on an otherwise complete diet, leaving out certain salts and obtained the following results: Omission of P, Cl, K, Na and Mg produced failure in growth; omission of either Na or K did not seem to check growth. This would indicate that the latter two are interchangeable in their use in the body.

Hart, McCollum and Fuller (108) fed five different lots of pigs rations containing varying amounts of minerals and obtained results showing that the pigs getting no P had weak bones, of low specific gravity and low ash. Those getting a liberal supply of inorganic P had heavier skeletons. They point out, however, that since the common feeding stuffs which are rich in protein are also high in P probably the P supply will be ample when rations are fed which are balanced according to the usual feeding standards.

Forbes (109) found that inorganic P was absorbed and

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retained and apparently utilized by growing pigs in the same manner as P in organic form.

Givens (110) has shown that fat has an important influence on mineral metabolism and is of prime importance in the nutrition of growth. Thus infants receiving a diet high in fat may have a negative balance of the alkalies and a reduction of the alkali earths. In a diet rich in cream the absorption of Ca dropped from 76 per cent to 34 per cent.

Hart and Steenbock (111) fed a pig on a ration consisting of wheat bran, corn and oat meal and concluded from their experiment "that bran was unfit as a bone producing feeding stuff because of its low content of lime rather than the disproportionate content of Ca and Mg."

McCollum and Davis (112) have studied the influence of the composition and amount of the mineral content of the ration on growth and reproduction on rats and concluded that:

(1) Young rats can grow normally and remain in apparent good health on rations whose base content varies widely in amount.

(2) Rations highly acid produced normal growth and apparent well-being.

(3) All lots failed to reproduce at normal intervals. This was due to an unexplained reason.

(4) Normal growth is in itself not sufficient evidence that a ration is fully adequate. Only when normal reproduction and rearing of young is repeated at normal intervals can a ration be said to be physiologically sufficient.

Lamb and Evaard (113) working with pigs confirmed the results obtained by McCollum and Davis on feeding rations highly acid. The pigs were able to reproduce themselves but were unsuccessful in rearing their young.

McCollum, Simmonds and Pitz (114) were unable to obtain growth on their rats on a ration consisting of mixtures of seeds, when distilled water was supplied. From their results they made the following generalization: "It is difficult, if not impossible, to obtain even a moderate amount of growth over an extended period on a diet restricted to seeds of plants." On the other hand "the leaf is distinctly different from the seed in its dietary properties in two respects: Its total inorganic content is very high, and it is especially rich in Na and Ca both of which are deficient in the seeds generally."

The above discussion of the mineral matter as regards the role it plays in nutrition shows that a proper supply and balance of minerals is indispensible to the well-being of both old and young animals. It has also been shown that, as a rule, a properly balanced ration is not likely to be deficient in mineral salts. It would seem, however, well to heed the advice of Kellner, or Hart and his co-workers, and feed to young dairy calves receiving milk, or milk and grain, an ounce of chalk or one-half ounce of ground rock phosphate daily.

Vitamines.

In 1911, Funk (115) gave the name of "vitamine" to substances which he believed to be curative of the disease called beri-beri. Today, the word vitamine is a common household term and its importance in nutrition is considered to be so great that in determining the diet of man or animal it is given first consideration. But this is not to be wondered at for all of the new

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discoveries in nutrition always, at first, assumed great magnitude in the role they play in nutrition, and the effect they have upon the well-being of the animal body. But in all cases, further investigations enabled scientists in due time to ascribe to these new factors the proper place they deserve in nutrition, and the same will undoubtedly be true of the vitamines.

Historical. Previous to 1909 all of the experiments in which attempts were made to nourish animals on purified nutrients have resulted in failures and in every case the cause of the failure was unknown (116).

In 1911 Osborne and Mendel (117) reported experiments in which they fed young rats on a diet consisting of purified proteins, carbohydrates, fat, and 28 per cent of "protein-free-milk", a preparation made by removing the casein of skimmilk with acid, albumen by coagulation with heat, and obtained normal growth. They attributed their success to the proper adjustment of the inorganic salts.

In the same year Funk (118) demonstrated that he could cure polyneuritis by administering to birds having this disease a substance which he obtained from the extracts of rice polishings. A little later he found that this substance was particularly abundant in brewer's yeast. This unknown factor Funk named "vitamine".

As far back as 1906, Hopkins (119) came to the conclusion that growth of the laboratory animals needed something in foods that could not be supplied by the ordinary nutrients. He gave to these hypothetical substances the name of "accessory food factors". He obtained very favorable results when small amount of milk was added to the food.

According to Eddy (120), in 1909, Stepp found that mice fed on a bread and milk diet grew normally. If the bread and milk mixture was extracted with alcohol - ether the residue was found to be inadequate for growth or maintenance. The substitution of purified fats corresponding to what was removed by the alcohol-ether produced no growth. When, however, the residue of the evaporated alcohol-ether extract of the bread and milk was returned to the diet, growth was resumed as before. Stepp concluded from these experiments that there was something connected up with the milk fats that was responsible for causing growth.

In 1913, McCollum and Davis (121) observed that normal growth was obtained when purified butter-fat or the ether extract of egg yolk was added to a mixture consisting of supposedly purified food substances. Lard and olive oil did not possess these growth stimulating properties.

The experiments cited clearly indicate that the various nutrition investigators were on the proper trail, that eventually led up to the discovery and differentiation of the growth stimulating complexes, the vitamines.

In 1912, Osborne and Mendel (122) reported experiments in which normal growth was obtained with rats over a period of 60 days on a ration of pure protein, starch, and "protein-free-milk", all the constituents being free from fats of any kind.

According to McCollum (123) "one phase of the difficulty was cleared for when fats of suitable character were present in the food mixture, growth was secured when 20 per cent of the diet consisted of nearly nitrogen-free lactose, but were unable to do so

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when the latter was replaced by starch. Obviously an impurity in the lactose furnished a second unknown dietary factor. Lactose with the omission of the fats of milk or egg yolk was attended with failure to attain growth."

In 1915, Funk and Macallum (124) found that young rats fed on purified nutrients, salts and butter-fat were unable to grow and died and some of them showed symptoms of beri-beri. They further found that the addition of yeast to this diet produced normal growth.

In the same year McCollum and Davis (125), as a result of careful investigation of the dietary deficiencies of rice, came to the conclusion "that there are necessary for growth two classes of unknown growth complexes." In 1916, McCollum and Kennedy (126) found that of the two accessory substances one was soluble in fats and accompanied them in the process of isolation from the food-stuffs, and the other soluble in water but apparently not in fats. They termed these two substances "Fat Soluble A" and "Water Soluble B".

Since then their work has been confirmed by many other investigators in this field of research and there now prevails the general agreement that these factors are indispensible for growth and nutrition of the animal.

We now come to the consideration of the third accessory factor, vitamine C. Scurvy has for many centuries been known as a disease due to improper diet. It was also known that when fruits and fresh vegetables formed a part of the diet that scurvy could be prevented and cured. It remained, however, for present-day investigators in nutrition to ascertain the etiology of this disease.

Between 1907 and 1912, Holst and Frohlich made extensive studies of the causes of scurvy and came to the conclusion that the cause was due to the absence in the diet of some such factor as in the case of beri-beri (127). Holst (128) demonstrated that a guinea-pig restricted to a diet of oats became affected with scurvy. Hess (129) further found that eggs and cod-liver oil, both rich in vitamine A were of no value as scurvy cures. Cohen and Mendel (130) showed that a mixture of yeast and butter supplying a sufficient quantity of both A and B gave no better results. These experiments clearly eliminated A and B as having any anti-scorbutic power.

McCollum (131) held a different view as to the cause of scurvy. He thought that scurvy in guinea-pigs was due to constipation. He was later convinced, however, that this disease was caused by the lack of an accessory factor in the food, different from A and B and which Drummond (132) finally named "Water Soluble C".

Still more recently another deficiency disease has been under investigation and results obtained suggest the possibility of an anti-rachitic vitamine, which will probably receive the name Vitamine D.

Attempts to determine the chemical nature of a vitamine has been made by some of the ablest chemists working in this field, notably, Funk, Osborne and Mendel, McCollum, Steenbock, Seidell and Williams, Drummond and others, but so far this problem remains unsolved. Considerable information has, however, been accumulated as regards the chemical and physiological properties of vitamines and these we will presently discuss.

Fat Soluble A, The Growth Vitamine. As the name indicates Vitamine A is soluble in fats. In 1918, McCollum and Simmonds (133) have shown that the animal has the power to separate the vitamine found in the food and store it in the body fat. Milk, for example, is rich or poor in Vitamine A according to the supply of the latter in the food given to the cow. Steenbock and his co-workers (134) as well as Drummond (135) have recently demonstrated that if butter fat is heated at 100° C for twelve hours in the presence of O_2, the vitamine will be destroyed. It has been shown (136) that hydrogenation destroys this vitamine; whereas, acid and alkali have practically no effect upon it.

From the standpoint of nutrition most investigators now agree that A and B and possibly C are necessary for growth. The absence of A in the diet also causes the characteristic eye disease which McCollum named Xerophthalmia (137).

As to the occurrence of A (138) it is found in butter fat, eggs, cod-liver oil, beef oil, oleomargarine, pig kidneys, pig liver, and liver oil, whale oil, seal oil, fish oil, milk; in corn, wheat germ, rye and oats, in leaves of plants, olive oil, millet and hemp seed, soy beans, peas and bananas and other similar foods.

Beri-beri or B Vitamine. Funk (139), McCollum (140) and others have shown that this complex is soluble in water, 95 per cent alcohol and benzene. Seidell (141) has demonstrated that B is absorbed by finally divided precipitates like fuller's earth; others have found that it is not easily affected by heat if the use of alkali is avoided.

The absence of this vitamine from the diet, as has been previously mentioned, produces beri-beri. Hess (144), Dutcher (143)

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and Hart (144) and others have obtained results to show that the vitamine content of a cow's milk is largely determined by her ration and as a consequence, the milk may be very poor in Vitamine B.

In the field of nutrition the absence of B vitamine is particularly marked by the stunting effect is has on growth. One of the most evident immediate affects of this complex is the increase of the appetite. Karr (145) has found that dogs which refused their basal diet would resume eating if they were allowed to injest separately a little yeast. The exact manner of the action of the vitamine in this connection still remains undetermined.

Vitamine B is found (146) in rich amounts in seeds, tubers, such as carrots, turnips, leaves, yeast, milk, eggs, and in fact it is widespread in nature.

Water Soluble C, the Antiscorbutic Vitamine. The properties of this vitamine are still less known. It is very unstable; it is soluble in water and is not absorbed by fuller's earth. Hess (147) has recently shown that oxygen is destructive to this vitamine. Mention has already been made that scurvy is a deficiency disease, due to the absence of C in the diet.

McCollum and Parsons suggest that even in animals where scurvy does not exist the presence of this factor may be necessary for normal metabolism.

The scources (148) of C are cabbage, lettuce, tomatoes, fresh berries of all kinds and especially such fruits and their juices as lemons, oranges, and limes, and other similar sources.

Sherman (149), in drawing an analogy between the animal body and the gasoline engine, states, in part, as follows: "The organic nutrients, fats, carbohydrates and proteins correspond to the fuel; the proteins and some of the mineral matters to materials of which the motor is made; other mineral matters to the lubricant; and the vitamine to the ignition sparks whose energy is insignificant, but without which the engine cannot run however fine the material of which it is built, or however abundant and appropriate the supplies of fuel and of lubricant."

Other Factors. There are other important factors that must be taken into consideration in the feeding of animals among which may be mentioned bulkiness, palatability, variety and water.

Bulkiness. Practical dairy men believe that bulkiness in a ration tends to increase the digestive capacity of dairy animals. In addition to this it is held that bulky feeds are necessary for proper digestion.

Experiments at the Illinois (150) and Iowa (151) experiment stations indicate that calves were unable to live on a ration consisting of milk and grain alone. Similar experiments conducted at the Kansas (152) and Minnesota (153) stations led to the conclusion that death was caused not by a lack of bulkiness in the ration, but because of Ca deficiency. An addition of Ca to the milk diet enabled the calves to make normal growth. However, even were it possible to raise calves on milk and grain alone, it would not be practical to do so, because a bulky ration is almost invariably also a more economical one.

Palatability. Palatability in a ration is important because of the stimulating effect it has on digestion and induces the animal to consume large quantities of feed. Eckles (154) points out that "an animal will give better results if it relishes its food." Jordan (155) states that "a successful ration must be palatable. 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 and is a requisite for the consumption of the necessary amount of food."

Succulence. Practical feeders and scientific investigators agree that succullence in a ration is a very essential factor. Eckles (156) states that "succulent feed such as silage and roots is especially palatable, and aids digestion in keeping the cow in good physical condition." Putney and Larson (157) state: "It is well known to practical feeders, and has been demonstrated by experiments, that cows will consume more feed, digest their feed better, and keep in better physical condition when the ration is made succulent by including some forms of green or other food high in moisture."

Variety. Skilled feeders usually maintain that a ration composed of a variety of feeds will give better results than when a smaller number are employed even though the latter ration supplies the proper amount of protein, carbohydrates and fat.

Eckles (158) states that "when a good ration is once selected, there is no advantage in making a change for the sake of variety. It has been claimed by some practical feeders that a change is beneficial but most of the successful herdsmen of dairy cattle select a ration carefully and make as few alterations as possible." Henry and Morrison (159) agree with Eckles in their observations that "with dairy cows, especially in the case of high-producing animals being forced on official test, skilled feeders place emphasis on having variety in the ration, though this does

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not imply changes in the ration from day to day. Indeed sudden changes in kinds of feed should be avoided."

Water. A discussion of the feeding of animals would, indeed, be very imcomplete without mentioning the role that water plays in the life of an animal.

According to Jordan (160), water fills an important part in the nutrition of all forms of life. "It acts as a solvent of the building materials which it carries from one part of the organism to another. It also serves as a carrier of waste. It is proper to speak of water as a building material for the animal body, for it is an abundant constituent of animal tissue and takes part in chemical changes such as hydrolysis. It fills an essential office in regulating the heat processes of the body thru varying rates of evaporation from the surface of the body."

It is a well known fact that animals can live longer without solid food than without water, as a lack of water in the body causes serious disturbances. The process of mastication, digestion, absorption and assimilation are hindered; the intestines are not properly flushed, the blood thickens, and the body temperature is increased. Such a condition soon results into death.

We may appropriately conclude the whole discussion on nutrition by quoting Hopkins who in speaking of the "law of minimum" said: "What we have actually to recognize is that each of several factors may become that which limits efficiency, and that no one of these is in any strict sense more important than any other. Normal nutrition calls for a certain minimum of each one and every one. If a diet is harmoniously balanced in a chemical sense, then indeed energy does become the sole limiting factor.

Nutrition then fails, of course, only when too little of the diet is eaten to yield the essential minimum of energy. But the supply of fat may become the limiting factor, and no less that of carbohydrate. Or, again, when the supply of energy consumed is ample, with fat and carbohydrate duly adjusted, the circumstance that a single essential amino acid in one case, or a vitamine in another, is present in amount below the necessary minimum converts each of these in turn into the factor which limits utilization. Small as the necessary minimum in either case may be, unless it is reached the proper use of the rest of the diet is reduced to a degree which is proportional to the deficiency. If the deficiency be complete normal utilization is altogether impossible."

ENERGY REQUIREMENTS FOR NORMAL GROWTH OF DAIRY HEIFERS.

In the literature reviewed the problem of growth has been discussed in a general way. What follows will take up the study of the subject having a more direct bearing on our problem.

<u>Feeding Standards for the Growth of Dairy Heifers</u>. A study of the different feeding standards brings to light the fact that only three of them have formulated the nutrient requirements for growing dairy heifers, namely the Wolf-Lehman, the Kellner, and the Armsby. Henry and Morrison (161) in presenting their Modified Wolf-Lehman standard have attempted to combine in one standard the best features of the different standards that are now available; they do not give, however, modified standards for growing dairy heifers nor for any other class of growing animals "on account of the lack of sufficient data".

The Wolf-Lehman (162) standard was formulated in 1897 and sets forth the requirements for growing dairy cattle in terms of crude protein, carbohydrates and fat. Later investigations in animal nutrition by experiment stations in this and other countries have shown that the Original Wolf-Lehman standards are in many instances inaccurate and this is especially true of digestible crude protein in which they are unnecessarily high.

The Kellner (163) standards give their nutrient requirements for "growing cattle and draft oxen" in terms of digestible crude protein and starch equivalents. The objection to this standard is that the requirements as given are not derived from actual experiments with growing dairy heifers, but are, for the most part, based on calculations from results obtained on the mature ox in the respiration calorimeter and are, therefore, only approximate estimates.

In 1909 Armsby (164) published the first standard for growing beef and dairy cattle, based on digestible protein and net energy values.

In 1916 (165) he presented a separate standard for growing dairy cattle; the nutrient requirements as given here are somewhat less than that presented in the previous standard. The following year he revised his standard again reducing the amount of protein somewhat, but requirements for total net energy was left the same as in the previous standard.

In presenting his standards Armsby frankly states that the nutrient requirements as set forth in them are not based on extensive determinations of the composition and energy values of the increase in live weight in growing animals, but are estimates "from such data as are avilable" and he hopes that "they may serve to give a general idea of the requirements per pound of growth of cattle at different ages " but that "they cannot lay claim to any degree of accuracy." Armsby's protein requirements are based on Kellner's standards and the energy requirements are estimates the basis for which are the results obtained with the mature ox in the respiration calorimeter as in Kellner's case.

Energy Requirements for Growing Dairy Heifers. As has previously been mentioned there is very little experimental data available that has a direct bearing on this subject. Some work has, however, been done in this connection, and from data originally meant to solve other problems, it was possible to make some calculations that would bring the work under the scope of our investigations.

Norton (166) kept records of feed consumed by 57 calves from birth until they were one year old. These animals were, for the most part, grades of both the leading dairy and beef breeds. Calculating from the data which he presents, the calves made a gain of 1.57 pounds per day for the 12 months and required 2.93 therms for each pound of gain. Armsby's standard allows three therms for the same rate of gain.

Eckles (167) collected data for five winters to determine the rations suitable for wintering growing dairy heifers. The experimental animals were purebred heifers of the Jersey, Holstein and Ayrshire breeds. From the data presented, Shaefer (168) found that 31 heifers consumed on the average 91.0 per cent of Armsby's energy requirements and made a gain of 108.0 per cent as compared to normal.

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Shaefer (169) kept feed records for a period of 110 days on twenty heifers whose average age at the beginning of the experiment was 11.5 months. The experimental animals used were representatives of the leading dairy breeds. The animals were divided into two groups consisting of ten animals in each. One of these groups received a ration containing 100.0% of Armsby's requirements for energy; the other group received a ration equal to 85.0% of Armsby's requirements for energy. The results obtained showed that the heifers receiving 100.0% of Armsby's standard made an average daily gain of 138.0% as compared to normal; those consuming 85.0% of Armsby's standard made an average daily gain of 123.0% as compared to normal. Shaefer concludes "that the energy requirements as set forth in Armsby's present feeding standard for growing heifers are unnecessarily high."

Williams (170) kept records of feed consumed by 16 young, grade Holstein calves in an experiment to determine the effect of feeding yeast foam equal to 10% of the total dry matter furnished by the ration. A summary of the results calculated from his data is presented in the following table.

This table shows that the average age for the lot was 22 days at the beginning of the experiment and that the duration of the trial was 164 days. During this time the 16 calves consumed, on the average, 109.7% of Armsby's energy requirements which enabled them to make an average daily gain of 106.8% as compared to normal, and a normal growth of 111.1% as compared to normal.

These results clearly show that for young calves of the Holstein breed the energy requirements as set forth in Armsby's standards are nearly correct. This may also hold true for calves

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Summary of Results Obtained in Feeding Young Calves in Yeast Foam Experiment.

Expr. animals	Days on experiment	Age at beginning	Average daily gain in weight	Gain as compared to normal	Average of normal weight	Energy compared to Armsby's standard
		Days	Pounds	Per cent	Per cent	Per cent
y-1	170	19	1.68	113.5	113.3	104.1
y-2	130	18	1.64	112.3	120.0	101.4
y-3	170	17	1.74	117.6	116.6	114.1
y-4	170	16	1.41	95.9	108.1	103.7
y-5	170	21	1.72	116.2	120.0	106.2
y-6	170	18	1.40	94.6	101.7	110.2
y-7	170	19	1.60	108.1	105.3	106.6
y-8	120	18	1.29	89.6	109.3	100.7
y-9	170	23	1.67	112.8	111.0	112.0
y-10	170	27	1.45	97.3	107.5	112.2
y-11	170	25	1.51	101.3	109.8	120.0
y-12	170	23	1.61	108.1	108.8	110.0
y-13	170	28	1.68	112.8	110.0	112.6
y-14	170	28	1.55	104.0	109.0	108.1
y-15	170	31	1.65	110.7	118.2	114.7
y-16	170	21	1.68	113.5	109.1	119.2
Average	164	22	1.58	106.8	111.1	109.7

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of the other dairy breeds of similar ages.

The subject matter reviewed shows that there is no satisfactory feeding standard for growing dairy heifers. The available data indicates that Armsby's standards are apparently nearly correct for young dairy calves making normal growth, but are too high for older dairy heifers and that the conclusions arrived at are based on limited data.

Experimental.

The discussion on nutrition of growing animals has brought out the fact that protein, carbohydrates, fats, mineral matter, vitamines and other factors are absolutely essential for the normal growth of animals. It has also been shown that according to the law of minimum the total net energy supplied an animal may also become the limiting factor in growth. An undersupply of total energy may thus prevent the animal from reaching its inherent size; on the other hand, the feeding of a ration supplying net energy above that necessary for making normal growth will result in waste and is, therefore, uneconomical. Further study of the subject disclosed that there are no feeding standards available that give the correct energy requirements for growing dairy heifers and that the data, so far collected is limited in scope, Further investigations along this line are, therefore, very desirable before a feeding standard giving the energy requirements for growing dairy heifers can be formulated.

Object of the Experiment. The purpose of this investigation is to determine the energy requirements for the normal growth of dairy heifers. The complete solution of this problem will necessitate the collection of data on many animals of the different dairy breeds and various ages, it is therefore evident that the best an experiment of this sort can do is to contribute some data which can be used in the ultimate solution of this problem.

Method of Investigation. There are two ways by which the problem of energy requirements for normal growth can be studied. The respiration calorimeter may be employed by means of which everything which passes into the animal - water, air and food - and everything which leaves the body - air, and solid and liquid excrements, is carefully measured, weighed and analyzed and the energy requirements determined. The other method and the one employed in these investigations, consists in taking a large number of animals and feeding them varying amounts of nutrients and then comparing the gains made by the animals with the established normal for the different breeds. It is obvious that the first method cannot be employed here because expensive apparatus, as well as a group of skilled chemists and attendants are necessary to conduct an experiment in a respiration calorimeter. Another objection to this method is that but few animals could be used and that they would be under more or less abnormal conditions while on trial. Under the feeding trial method large numbers of animals may be employed which would tend to eliminate errors due to individuality. The conditions under which the experiment is conducted when followint this method comes much closer to duplicating the farmers environments and therefore such results may come even nearer to determining the actual energy requirements necessary for normal growth. It is not to be overlooked, however, that this method also has its weak points. The exact composition of the feed consumed

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by the experimental animals is not known and there is always some food wasted , or some extra food eaten, as when the animals are bedded with straw, which tends to bring in an error.

Plan of the Experiment. In the planning of this experiment the animals were divided into two groups as nearly equal as to breed, age, and individuality as possible. One group consisting of five heifers was to receive 100.0% of Armsby's energy requirements; the other group consisting of four heifers, was to be kept at the same normality as when placed on experiment after a ten-day preliminary trial. For instance, if a heifer was found to be 116% normal at the beginning of the trial it was the purpose to keep her at this normality throughout the whole length of the experiment, independent of the amount of energy it required to do so.

Since Armsby's standard expresses the requirements for growing dairy heifers in terms of net energy and since it is probably more nearly correct than the other two, it was decided to use this standard as a guide in formulating the rations for the experimental animals.

No definite length was set for the duration of the experiment but it lasted 150 days.

Experimental Animals. A total of 9 heifers was used in this experiment ranging in age from 187 to 333 days when placed on trial; they were all pure-breds and were dropped in the University of Minnesota herd; the whole group consisted of three Ayrshires (No's. 15, 17 and 18); four Jerseys (No's. 140, 141, 142 and 143); and two Holsteins (No's. 360 and 361).

Method of Feeding. The experimental animals were fed grain and roughage twice daily. The grain mixture consisted of

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corn meal 4 parts, bran 1 part, and oil meal 1 part, by weight; the roughage was alfalfa hay and corn silage. Salt and mineral matter in the form of ground bone meal was kept in separate boxes in the yard where the heifers could help themselves ad libitum.

The rations were computed according to Armsby's standard. The protein and energy supplied includes the sum of that necessary for maintenance and to make normal gains. At the beginning of the trial the plan was to feed as much roughage as possible and a small amount of grain; towards the end of the experiment some of the heifers and especially those receiving 100% of Armsby's standard failed to consume all of the ration alloted to them, and in order to induce them to eat the full requirements of energy the amount of roughage had to be decreased and the grain increased. The feed not eaten was weighed back and recorded on special sheets provided for this purpose.

The above is a practical ration used in the feeding of the University herd calves and in the light of our present knowledge of nutrition is considered adequate in every respect to make normal growth.

The heifers were kept in stanchions when in the barn; were let out for water at least once a day; and were permitted to exercise in the yard for several hours during the day when the weather permitted.

<u>Weighing and Measuring</u>. The heifers were weighed and measured when placed on the experiment and after that they were weighed every ten days once and at the end of every thirty days for three consecutive days; the average of the three weighings being used as the correct one. The measurements at the withers were made

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to determine the growth of skeleton; an ordinary measuring standard graduated in centimeters being used for this purpose. This was done with the animal standing on a level floor in a normal position and measured three times, the animal being moved after each measurement to prevent an error due to the sinking of the back, because of the relaxation of muscles when standing in one place; the average of the three measurements was used as the correct figure. The weights and measurements obtained were used in computing rations and for comparing with normal growth. New rations were computed after every weigh period.

Discussion of Data.

Before taking up any further discussion of this problem it will be necessary to have a clear understanding as to what is meant by normal growth for dairy heifers and how growth is measured.

Normal growth as used here is based on investigations conducted by Eckles (171) and represents the average growth of most of the heifers of the Jersey, Holstein, and Ayrshire breeds that were dropped and raised at the University of Missouri herd extending over a period of about seven years - a separate normal having been established for each of the breeds mentioned.

Eckles (172) has also made an extensive study of the methods of measuring growth of dairy cattle. He maintains, together with others, that body weight in itself is not a satisfactory method of measuring growth, because it has been found that "body weight and skeletal growth are to a considerable degree independent of each other", but that increase body weight and skeleton should both be used to measure growth.

In studying the methods best adapted for measuring skeletal growth he found that "the growth of the various parts of the body proceeds in rather definite ratios." In other words, there is a striking correlation between the increase in size of one part of the skeleton with that of any other part and "since the error in taking measurements which represent the height at withers seems to be as slight as any and to be effected to as small extent as any by varying conditions of the animal, this measurement has been chosen as a standard to represent skeletal growth development" and is the one used in this experiment to measure skeletal growth.

We can now proceed with the discussion of the data.

Table I gives the normal weight and height at the withers for the different ages, in month intervals, of the Jersey, Holstein, and Ayrshire breeds as determined by Eckles at the Missouri station (173). The gains made by the experimental animals were compared with these values and the per cent normal computed. The normal growth as given in this table thus served the purpose of control animals.

Table IA represents Armsby's requirements for growth, including maintenance. This table gives the digestible protein and net energy required by animals of different ages and weights. Armsby's standard was used as a guide in computing the rations for the experimental animals and also for comparing with it the energy consumed by animals not receiving 100% of this standard.

Tables II to XI inclusive represent the records and computations for group I, consisting of five animals and receiving energy equal to 100% of Armsby's standard. There are two tables

Table I. Normal Weights and Heights for Dairy Heifers

Age	Ayrshire		Jersey		Holstein	
	Weight	Height at withers	Weight	Height at withers	Weight	Height at withers
Months	Pounds	Cm.	Pounds	Cm.	Pounds	Cm.
6	286	92.6	260	93.7	349	100.9
7	304	94.8	302	96.8	389	104.0
8	336	97.8	340	99.8	425	107.1
9	366	99.1	376	102.4	466	109.1
10	406	100.8	407	105.0	501	111.2
11	427	101.9	432	106.5	529	112.6
12	456	103.5	456	108.3	558	114.0
13	485	105.0	480	110.1	574	115.7
14	533	106.8	503	111.4	596	117.4
15	547	107.8	520	112.7	612	118.8
16	560	108.5	533	113.4	643	120.3
17	579	109.5	553	114.6	660	121.3
18	604	111.2	572	115.6	686	121.8
19	627	112.3	598	116.8	715	122.7
20	651	113.4	621	117.5	746	123.8

Table IA. Armsby's Requirements for Growth and Maintenance of Dairy Cattle.*

Age	Live Weight	Digestible Protein	Net Energy
Months	Pounds	Pounds	Therms
1	100	0.40	3.1
2	135	0.45	3.4
3	165	0.55	3.6
6	275	0.70	4.1
9	325	0.75	4.4
12	400	0.80	5.1
18	550	0.85	6.4
24	700	0.85	7.6
30	800	0.85	8.2

* Armsby's Nutrition of Farm Animals, p. 713.

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for each animal and they show the age in days; the weight by 10-day periods; the weight as compared to normal; the net energy supplied and consumed and the per cent energy as compared to Armsby's standard; the amount and kind of food eaten; and the actual and normal gains made in height and weight.

Tables XII to XIX inclusive represent the records and computations for group II consisting of four heifers and receiving sufficient energy to maintain the same normality of growth as they were found to be after the ten day preliminary trial. The records shown in these tables do not differ in any way from those just described.

Table XX gives a summary of the results and a comparison of both groups. This table represents the age and weight at the beginning of the experiment; the average normal and actual daily gain in weight and the gain as compared to normal; also the per cent of energy consumed. as compared to Armsby's standard.

Table XXI gives similar results and comparisons for skeletal growth.

Table XXII shows the relation of breed to gain in weight and height of group I and II and the energy consumed as compared to Armsby's standard.

Table XXIII gives the relation of age to gain in weight and height and the energy consumed as compared to Armsby's standard.

In discussing the data given in the above mentioned tables gain in weight only will be mentioned, because it is the most important factor in representing growth and also because the duration of the experiment was too short to obtain data sufficiently reliable to draw any conclusions as to the relation between the amount of energy consumed and skeletal growth.

Group I Receiving Energy According to Armsby's Standard. The data showing the progress of these animals is tabulated in tables II to XI inclusive. A study of these tables brings out the following facts:

Ayrshire heifer No. 15 was 291 days old when placed on experiment; her average weight for the trial was 509 pounds; she consumed 99.8% of Armsby's standard and made an average daily gain of 125.3% as compared to normal.

Ayrshire heifer No. 18 was 197 days old at the beginning of the trial; her average weight was 353 pounds; she received 100.0% of Armsby's energy requirements and made an average daily gain of 99.0% as compared to normal.

Jersey heifer No. 140, when placed on experiment, was 343 days old and her average weight for the trial was 607 pounds; she consumed 94.8% of Armsby's standard which enabled her to make an average daily gain of 131.8% as compared to normal.

Jersey heifer No. 142, when placed on trial, was 251 days old and her average weight for the duration of the experiment was 423 pounds; she received 100.7% of Armsby's energy requirements and made an average daily gain of 128.9% as compared to normal.

Holstein heifer No. 361 was 270 days old at the beginning of the experiment; her average weight for the trial was 665 pounds; she consumed 99.0% of Armsby's requirements for energy and made an average daily gain of 172.0% as compared to normal.

It will be recalled that the original plan for this group was that the animals consume energy according to Armsby's standard; some of the heifers failed to do so, because the hay fed to them was of poor quality and they did not eat up all that was allotted to them. A striking difference is noticed in the way individual heifers make use of the energy consumed; thus the youngest heifer, No. 18, made only 99.0% gain as compared to normal on 100.0% of Armsby's standard; whereas heifer No. 140, the oldest of the group, consuming 94.8% of Armsby's standard made a gain of 131.8% as compared to normal. This may be explained by Armsby's requirements not being correct for all ages. But heifer No. 361, midway between the two heifers in age, made a gain of 172.0% as compared to normal on 99.0% of Armsby's standard. Just why she made this high gain is not clear. She was in a high state of flesh when placed on experiment, but so was heifer No. 140, neither did she appear to be of a quieter disposition than the rest of the heifers in the group. This is evidently an illustration of one of the many unaccountable occurrences in nutrition which is explained as being due to individuality.

Table No. II. Aryshire Heifer No. 15.
Record of Weights and Nutrients Received.
Receiving Energy According to Armsby's Standard.
Average per Day by 10-Day Periods.

Age	Weight	Weight compared to normal	Dig.Crude Protein		Net Energy		Amount of Armsby's standard consumed
			Armsby's standard	Supplied	Armsby's standard	Supplied	
Days	Pounds	Per cent	Pounds	Pounds	Therms	Therms	Per cent
291	421	106.9	0.80	1.14	5.28	5.45	103.1
301	442	108.6	0.81	1.16	5.46	5.61	102.7
311	445	107.6	0.81	1.16	5.49	5.61	102.1
321	459	109.1	0.81	1.16	5.61	5.61	99.9
331	467	109.1	0.82	1.16	5.68	5.61	98.7
341	480	109.7	0.82	1.26	5.79	5.54	95.7
351	491	109.8	0.82	1.23	5.89	5.44	92.4
361	506	110.7	0.83	1.01	6.01	5.92	98.4
371	515	110.4	0.83	1.14	6.09	6.06	99.6
381	540	113.4	0.84	1.15	6.31	6.30	99.9
391	524	107.7	0.84	1.15	6.17	6.30	102.2
401	547	108.8	0.84	1.08	6.37	6.44	101.1
411	561	108.2	0.85	1.08	6.48	6.44	99.3
421	565	105.9	0.85	1.18	6.52	6.62	101.6
431	573	106.5	0.85	1.22	6.58	6.56	99.7
441	601	110.7	0.85	1.32	6.80	6.82	100.3
Total	8137	1743.1	13.33	18.67	96.60	96.39	1596.7
Ave.	509	108.9	0.83	1.16	6.03	6.02	99.8

Table No. III. Aryshire Heifer No. 15.
Feed Consumed and Gain in Weight and Height.
Receiving Energy According to Armsby's Standard.

Weight by 10-Day Periods and Height
by 30-Day Periods.

	Grain mixture	Hay	Silage	Gain in Weight		Gain in Height	
				Actual	Normal	Actual	Normal
	Pounds	Pounds	Pounds	Pounds	Pounds	Centimeters	Centimeters
	3.0	7.0	4.0				
	3.0	7.0	5.0	2.1	1.27		
	3.0	7.0	5.0	0.3	0.70	0.6	0.5
	3.0	7.0	5.0	1.4	0.70		
	3.0	7.0	5.0	0.8	0.72		
	2.5	8.0	6.0	1.3	0.97	2.4	1.3
	2.5	7.7	6.0	1.1	0.97		
	3.5	5.8	7.0	1.5	0.96		
	3.5	6.0	7.5	0.9	0.97	1.6	1.7
	3.5	6.0	9.0	2.5	0.97		
	3.5	6.0	9.0	-1.6	0.93		
	3.5	5.0	12.0	2.3	1.60	1.5	1.6
	3.5	5.0	12.0	1.4	1.60		
	3.5	6.0	11.0	1.0	1.48		
	3.0	7.0	11.0	0.8	0.47	2.2	1.5
	3.0	8.0	10.5	2.8	0.47		
Total	50.5	105.5	125.0	180.0	148.8	8.3	6.6
Ave.	3.2	6.6	7.8	1.20	0.99	1.9	1.5

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Table No. IV. Aryshire Heifer No. 18.
Record of Weights and Nutrients Received.
Receiving Energy According to Armsby's Standard.
Average per Day by 10-Day Periods.

Age	Weight	Weight compared to normal	Dig. Crude Protein		Net Energy		Amount of Armsby's standard consumed
			Armsby's standard	Supplied	Armsby's standard	Supplied	
Days	Pounds	Per cent	Pounds	Pounds	Therms	Therms	Per cent
197	276	97.2	0.70	0.80	4.10	4.25	103.6
207	289	95.6	0.71	0.86	4.18	4.27	101.8
217	301	96.7	0.72	0.80	4.26	4.08	96.0
227	309	95.9	0.73	0.86	4.30	4.35	101.1
237	318	95.6	0.74	0.86	4.36	4.35	99.9
247	326	95.0	0.75	0.97	4.41	4.54	103.0
257	332	94.1	0.75	0.97	4.46	4.54	101.7
267	338	93.1	0.75	0.85	4.52	4.49	99.3
277	354	94.3	0.76	0.82	4.67	4.47	95.6
287	370	95.2	0.77	0.90	4.82	4.83	100.2
297	369	91.8	0.77	0.90	4.81	4.83	100.4
307	393	95.6	0.79	0.91	5.03	5.07	100.7
317	397	95.0	0.79	0.91	5.07	5.07	99.9
327	404	95.1	0.80	0.96	5.13	5.16	100.5
337	425	98.0	0.80	0.96	5.32	5.16	97.1
347	439	99.0	0.81	1.06	5.44	5.42	99.7
Total	5640	1527.2	12.22	14.46	74.95	74.96	1600.5
Ave.	353	95.5	0.76	0.90	4.68	4.68	100.0

Table No. V. Aryshire Heifer No. 18.
Feed Consumed and Gain in Weight and Height.
Receiving Energy According to Armsby's Standard.

Weight by 10-Day Periods and Height
by 30-Day Periods.

	Grain mixture	Hay	Silage	Gain in Weight		Gain in Height	
				Actual	Normal	Actual	Normal
	Pounds	Pounds	Pounds	Pounds	Pounds	Centimeters	Centimeters
	4.0	3.0	0.0				
	3.0	4.5	0.0	1.3	0.60		
	3.0	3.9	2.0	1.2	0.92	0.5	0.8
	3.0	4.5	2.5	0.8	1.07		
	3.0	4.5	2.5	0.9	1.07		
	2.5	6.0	3.0	0.2	1.02	4.7	2.6
	2.5	6.0	3.0	0.6	1.00		
	3.0	4.2	4.0	0.6	1.00		
	3.0	3.9	4.5	1.6	1.23	3.2	1.4
	3.0	4.5	5.5	1.6	1.33		
	3.0	4.5	5.5	-0.1	1.34		
	3.0	4.5	7.0	2.4	0.89	0.6	1.6
	3.0	4.5	7.0	0.4	0.70		
	3.0	5.0	6.5	0.7	0.70		
	3.0	5.0	6.5	2.1	0.88	3.0	1.2
	3.0	6.0	6.0	1.4	0.97		
Total	48.0	74.6	65.5	163.0	147.2	12.0	7.6
Ave.	3.0	4.7	4.1	1.08	0.98	2.8	1.8

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Table No. VI. Jersey Heifer No. 140.
Record of Weights and Nutrients Received.
Receiving Energy According to Armsby's Standard.
Average per Day by 10-Day Periods.

Age	Weight	Weight compared to normal	Dig. Crude Protein		Net Energy		Amount of Armsby's standard consumed
			Armsby's standard	Supplied	Armsby's standard	Supplied	
Days	Pounds	Per cent	Pounds	Pounds	Therms	Therms	Per cent
343	555	125.5	0.85	1.38	6.44	6.45	100.2
353	564	125.2	0.85	1.23	6.51	6.00	92.3
363	567	123.7	0.85	1.34	6.53	6.36	97.4
373	575	123.3	0.85	1.30	6.60	6.31	95.6
383	590	124.4	0.85	1.40	6.72	6.61	98.5
393	596	123.6	0.85	1.46	6.76	6.79	100.4
403	590	120.4	0.85	1.46	6.72	6.79	101.1
413	583	117.2	0.85	0.91	6.66	5.57	83.6
423	599	118.7	0.85	1.12	6.79	6.29	92.6
433	619	121.3	0.85	1.16	6.95	6.42	92.5
443	603	116.9	0.85	1.10	6.82	6.23	91.3
453	631	121.0	0.85	1.04	7.04	6.43	91.2
463	641	121.9	0.85	1.16	7.12	6.80	95.5
473	653	122.9	0.85	1.16	7.22	6.82	94.5
483	660	123.5	0.85	1.17	7.28	6.99	96.1
493	685	126.5	0.85	1.12	7.48	7.04	94.2
Total	9711	1956.0	13.60	19.59	109.68	103.97	1517.0
Ave.	607	122.3	0.85	1.22	6.85	6.49	94.8

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Table No. VII. Jersey Heifer No. 140.
Feed Consumed and Gain in Weight and Height.
Receiving Energy According to Armsby's Standard.

Weight by 10-Day Periods and Height
by 30-Day Periods.

	Grain mixture	Hay	Silage	Gain in Weight		Gain in Height	
				Actual	Normal	Actual	Normal
	Pounds	Pounds	Pounds	Pounds	Pounds	Centimeters	Centimeters
	3.0	9.0	6.0				
	2.5	7.9	8.0	0.9	0.80		
	2.5	9.0	8.0	0.3	0.80	0.1	0.6
	2.5	8.6	8.5	0.8	0.80		
	2.5	9.5	8.5	1.5	0.80		
	2.0	10.5	10.0	0.6	0.79	1.7	1.7
	2.0	10.5	10.0	-0.6	0.76		
	3.0	4.1	11.0	-0.7	0.77		
	3.0	6.0	11.5	1.6	0.71	3.4	1.3
	3.0	6.4	11.5	2.0	0.57		
	3.0	5.8	11.5	-1.6	0.56		
	3.5	4.5	13.0	2.8	0.53	0.9	1.3
	3.5	5.6	13.0	1.0	0.33		
	3.5	5.6	13.0	1.3	0.57		
	4.0	5.2	12.5	0.7	0.30	0.0	0.7
	4.0	5.8	11.5	2.5	0.74		
Total	47.5	114.2	167.5	130.0	99.3	6.1	5.5
Ave.	3.0	7.1	10.5	0.87	0.66	1.4	1.3

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Table No. VIII. Jersey Heifer No. 142.
Record of Weights and Nutrients Received.
Receiving Energy According to Armsby's Standard.
Average per Day by 10-Day Periods.

Age	Weight	Weight compared to normal	Dig. Crude Protein		Net Energy		Amount of Armsby's standard consumed
			Armsby's standard	Received	Armsby's standard	Received	
Days	Pounds	Per cent	Pounds	Pounds	Therms	Therms	Per cent
251	337	95.7	0.75	0.86	4.51	4.58	101.5
261	355	97.0	0.76	0.89	4.68	4.82	103.1
271	365	96.8	0.77	1.02	4.77	4.79	100.3
281	379	97.8	0.78	1.03	4.90	4.95	100.9
291	397	99.8	0.79	1.13	5.07	5.06	99.7
301	406	99.6	0.80	1.22	5.15	5.17	100.3
311	402	96.6	0.80	1.22	5.12	5.17	101.0
321	421	99.2	0.80	1.06	5.28	4.38	93.0
331	422	97.5	0.80	1.02	5.29	5.26	99.4
341	445	101.0	0.81	1.15	5.49	5.70	103.9
351	437	97.4	0.81	1.18	5.42	5.77	106.5
361	460	100.7	0.81	0.98	5.62	5.60	99.7
371	463	99.6	0.82	0.99	5.64	5.62	99.6
381	478	101.1	0.82	1.09	5.77	5.82	100.7
391	497	103.4	0.83	1.18	5.94	6.00	101.0
401	511	104.6	0.83	1.19	6.06	6.08	100.4
Total	6775	1587.8	12.86	17.46	84.79	84.83	1611.0
Ave.	423	99.2	0.80	1.09	5.29	5.30	100.7

Table No. IX. Jersey Heifer No. 142.
Feed Consumed and Gain in Weight and Height.
Receiving Energy According to Armsby's Standard.

Weight by 10-Day Periods and Height
by 30-Day Periods.

	Grain Mixture	Alfalfa Hay	Corn Silage	Gain in Weight		Gain in Height	
				Actual	Normal	Actual	Normal
	Pounds	Pounds	Pounds	Pounds	Pounds	Centimeters	Centimeters
	4.0	3.5	1.0				
	3.5	4.0	4.0	1.8	1.30		
	3.0	6.0	2.0	1.0	1.18	1.3	1.0
	3.0	6.0	3.0	1.4	1.04		
	2.5	7.5	3.0	1.8	1.03		
	2.0	9.0	3.0	0.9	1.01	2.5	2.2
	2.0	9.0	3.0	-0.4	0.84		
	2.5	6.7	5.0	1.9	0.73		
	2.5	6.0	7.5	0.1	0.83	0.6	1.5
	2.5	7.3	7.5	2.3	0.80		
	2.5	7.5	7.5	-0.8	0.80		
	3.0	4.9	9.5	2.3	0.80	2.5	1.8
	3.0	4.9	9.5	0.3	0.80		
	3.0	6.0	8.5	1.5	0.80		
	3.0	7.0	7.0	1.9	0.80	2.1	1.7
	3.0	7.0	8.0	1.4	0.76		
Total	45.0	102.4	89.0	174.0	136.2	9.0	8.2
Ave.	2.8	6.4	5.6	1.16	0.90	2.1	1.9

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Table No. X. Holstein Heifer No. 361.
Record of Weights and Nutrients Received.
Receiving Energy According to Armsby's Standard.
Average per Day by 10-Day Periods.

Age	Weight	Weight compared to normal	Dig. Crude Protein		Net Energy		Amount of Armsby's standard consumed
			Armsby's standard	Consumed	Armsby's standard	Consumed	
Days	Pounds	Per cent	Pounds	Pounds	Therms	Therms	Per cent
270	559	120.0	0.85	1.38	6.47	6.45	99.7
280	577	120.7	0.85	1.31	6.61	6.28	95.0
290	585	119.6	0.85	1.33	6.68	6.40	95.9
300	589	117.6	0.85	1.39	6.71	6.64	99.0
310	609	119.3	0.85	1.40	6.87	6.69	97.4
320	635	122.1	0.85	1.59	7.08	7.06	99.8
330	634	119.8	0.85	1.59	7.07	6.98	98.8
340	655	121.6	0.85	1.41	7.24	7.18	99.2
350	662	120.7	0.85	1.43	7.29	7.24	99.4
360	697	124.9	0.85	1.46	7.57	7.56	99.9
370	696	123.6	0.85	1.46	7.56	7.56	100.0
380	713	125.4	0.85	1.37	7.67	7.61	99.2
390	735	128.0	0.85	1.42	7.81	7.78	99.7
400	741	127.5	0.85	1.47	7.84	7.87	100.4
410	768	130.4	0.85	1.48	8.00	8.03	100.4
420	784	131.5	0.85	1.57	8.09	8.14	100.5
Total	10639	1972.7	13.60	23.13	116.61	115.56	1584.3
Ave.	665	123.3	0.85	1.44	7.28	7.22	99.0

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Table No. XI. Holstein Heifer No. 361.
Feed Consumed and Gain in Weight and Height.
Receiving Energy According to Armsby's Standard.

Weight by 10-Day Periods and Height by 30-Day Periods.

	Grain mixture	Alfalfa Hay	Corn Silage	Gain in Weight		Gain in Height	
				Actual	Normal	Actual	Normal
	Pounds	Pounds	Pounds	Pounds	Pounds	Centimeters	Centimeters
	3.0	9.0	6.0				
	2.5	8.7	8.0	1.8	1.17		
	3.0	8.4	7.0	0.8	1.16	0.2	0.7
	3.0	9.0	7.2	0.4	1.17		
	3.0	9.0	7.5	2.0	0.93		
	2.5	11.5	7.0	2.6	0.94	3.4	1.6
	2.5	11.0	7.0	-0.1	0.93		
	3.0	8.8	11.0	2.1	0.97		
	3.0	9.0	11.0	0.7	0.96	1.6	1.4
	3.0	9.0	13.0	3.5	0.97		
	3.0	9.0	13.0	-0.1	0.53		
	3.5	7.5	14.0	1.7	0.54	1.0	1.6
	3.5	8.0	14.0	2.2	0.53		
	3.5	8.5	13.5	0.6	0.73		
	3.5	8.5	14.5	2.7	0.74	3.0	1.7
	3.5	9.5	13.0	1.6	0.73		
Total	49.0	144.5	166.7	225.0	130.0	9.2	7.0
Ave.	3.1	9.0	10.4	1.5	0.87	2.1	1.6

Group II Receiving Energy Sufficient to Make Normal Growth. Tables XII to XIX inclusive give the complete data pertaining to the animals of this group. A study of the results brings out the following observations:

Ayrshire heifer No. 17, when placed on experiment, was 236 days old and was 110.6 as compared to normal; her average normal for the duration of the trial was 112.9%; her average weight for the duration of the trial was 460 pounds; she consumed 94.0% of Armsby's energy requirements and made an average daily gain of 129.0% as compared to normal.

Jersey heifer No. 141 was 276 days old when placed on trial; she was 105.2% as compared to normal and the average normal for the duration of the trial was 109.6%; her average weight was 482 pounds; she consumed 96.1% of Armsby's standard which enabled her to make a daily gain of 132.0% as compared to normal.

Jersey heifer No. 143, when placed on experiment, was 206 days old; she was 96.5% as compared to normal and the average normal for the duration of the experiment was 95.6%; she consumed 105.2% of Armsby's energy requirements which enabled her to make a gain of 105.8% as compared to normal.

Holstein heifer No. 360, at the beginning of the experiment was 306 days old and 118.4% as compared to normal growth; the average normal for the duration of the trial was 120.2; her average weight was 682 pounds; she consumed 85.1% of Armsby's standard and made an average daily gain of 135.1% as compared to normal.

The animals in this group showed a similar response in growth to energy consumed; the younger heifers requiring more energy to maintain the normal as found at the beginning of the experiment, the older ones less. The growth impulse showed itself the strongest in heifer No. 360 as she required the least energy to maintain the normal she started with. Towards the end of the experiment she used less than 50% of Armsby's standard to maintain her 18% above normal growth.

Summary and Comparison of Results of Both Groups. Tables XX and XXI and chart I give a summary and comparison of the results of both groups. The chart is self explanatory. A study of these tables shows that the average age for group I was 270 days and the weight 430 pounds; the animals consumed 98.9% of Armsby's energy requirements and made an average gain of 130.3% as compared to normal.

The average age for group II was 256 days and the weight 414 pounds; the heifers consumed 95.1% of Armsby's standard which enabled them to make a gain of 125.5% as compared to normal.

These results show that there was practically no difference in the gains made by each group as compared to normal when the amount of food consumed is taken into consideration.

Assuming that 100% of Armsby's standard is calculated to make 100% normal growth, the results obtained would tend to show that for dairy heifers at this age, the energy requirements as set forth in Armsby's standard are about 30% too high.

Relation of Breed to Gain in Weight and Height. Table XXII gives the data showing the relation of breed to gain in weight and height for each group separately and for both groups combined. The number of animals in each group representing the different breeds is too small to warrant a detailed discussion.

Table No. XII. Ayrshire Heifer No. 17.
Record of Weights and Nutrients Received.
Receiving Energy Sufficient to Make Normal Growth.
Average per Day by 10-Day Periods.

Age	Weight	Weight compared to normal	Dig. Crude Protein Armsby's standard	Dig. Crude Protein Consumed	Net Energy Armsby's standard	Net Energy Consumed	Amount of Armsby's standard consumed
Days	Pounds	Per cent	Pounds	Pounds	Therms	Therms	Per cent
236	367	110.6	0.77	0.91	4.79	4.52	94.3
246	384	112.2	0.78	0.83	4.95	4.35	87.8
256	396	112.5	0.79	0.94	5.06	4.92	97.4
266	410	113.3	0.80	1.05	5.19	5.26	101.5
276	423	113.1	0.80	1.05	5.30	5.26	99.3
286	435	112.3	0.81	1.16	5.40	5.53	102.4
296	433	118.1	0.81	1.16	5.38	5.53	102.7
306	451	109.9	0.81	1.04	5.54	5.48	98.9
316	459	110.0	0.81	0.96	5.61	5.41	96.4
326	483	113.9	0.82	1.04	5.82	5.65	97.1
336	484	111.8	0.82	1.04	5.83	5.65	97.0
346	499	112.8	0.83	0.95	5.96	5.54	93.1
356	512	113.2	0.83	0.95	6.06	5.54	91.4
366	524	113.5	0.84	0.95	6.17	5.54	89.9
376	536	113.7	0.84	0.99	6.28	5.40	86.0
386	557	115.8	0.85	0.81	6.45	4.43	68.6
Total	7353	1806.7	13.09	15.88	89.86	84.10	1503.8
Ave.	460	112.9	0.81	0.99	5.61	5.25	94.0

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Table No. XIII. Aryshire Heifer No. 17.
Feed Consumed and Gain in Weight and Height.
Receiving Energy Sufficient to Make Normal Growth.

Weight by 10-Day Periods and Height
by 30-Day Periods.

Grain mixture Pounds	Alfalfa hay Pounds	Corn silage Pounds	Gain in Weight Actual Pounds	Gain in Weight Normal Pounds	Gain in Height Actual Centimeters	Gain in Height Normal Centimeters
3.5	4.5	1.0				
2.5	4.5	5.0	1.7	1.03		
3.0	5.0	5.0	1.2	1.00	0.8	0.7
3.0	6.0	5.0	1.4	1.00		
3.0	6.0	5.0	1.3	1.20		
2.5	7.5	6.0	1.2	1.33	3.3	2.5
2.5	7.5	6.0	-0.2	1.33		
3.0	5.7	7.0	1.8	0.96		
3.0	4.8	8.5	0.8	0.70	1.5	1.4
3.0	5.5	8.5	2.4	0.70		
3.0	5.5	8.5	-0.1	0.86		
3.0	4.5	10.0	1.5	1.00	2.6	1.4
3.0	4.5	10.0	1.3	0.93		
3.0	4.5	10.0	1.2	0.97		
2.5	5.5	9.5	1.2	0.96	3.5	1.5
1.5	5.0	9.5	2.1	0.97		
Total 45.0	86.5	114.5	190.0	149.4	11.7	7.5
Ave. 2.8	5.4	7.2	1.29	1.00	2.7	1.7

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Table No. XIV. Jersey Heifer No. 141.
Record of Weights and Nutrients Received.
Receiving Energy Sufficient to Make Normal Growth.
Average per Day by 10-Day Periods.

Age	Weight	Weight compared to normal	Dig. Crude Protein		Net Energy		Amount of Armsby's standard consumed
			Armsby's standard	Consumed	Armsby's standard	Consumed	
Days	Pounds	Per cent	Pounds	Pounds	Therms	Therms	Per cent
276	402	105.2	0.80	1.05	5.12	5.34	104.3
286	420	107.0	0.80	1.01	5.27	5.25	99.6
296	427	106.0	0.80	1.03	5.33	5.29	99.2
306	441	107.0	0.81	1.06	5.45	5.42	99.4
316	450	107.1	0.81	1.06	5.53	5.42	98.0
326	463	108.0	0.82	1.22	5.64	5.86	103.9
336	473	108.3	0.82	1.19	5.73	5.76	100.5
346	479	107.7	0.82	1.08	5.78	5.74	99.3
356	486	107.3	0.82	1.07	5.84	5.75	98.4
366	500	108.5	0.83	1.09	5.96	5.82	97.6
376	507	108.1	0.83	1.06	6.02	5.72	94.9
386	509	106.8	0.83	1.05	6.04	5.89	97.5
396	532	109.8	0.84	1.04	6.24	5.73	91.8
406	528	107.3	0.84	1.04	6.20	5.73	92.3
416	540	108.0	0.84	1.04	6.31	5.73	90.8
426	560	110.6	0.85	0.98	6.48	4.55	70.4
Total	7717	1722.7	13.22	17.15	93.03	89.07	1537.9
Ave.	482	107.7	0.82	1.07	5.81	5.56	96.1

Table No. XV. Jersey Heifer No. 141.
Feed Consumed and Gain in Weight and Height.
Receiving Energy Sufficient to Make Normal Growth.

Weight by 10-Day Periods and Height by 30-Day Periods.

	Grain mixture	Alfalfa hay	Corn silage	Gain in Weight		Gain in Height	
				Actual	Normal	Actual	Normal
	Pounds	Pounds	Pounds	Pounds	Pounds	Centimeters	Centimeters
	3.0	5.5	4.0				
	3.0	5.5	6.0	1.8	1.03		
	3.0	5.7	5.8	0.7	1.04	0.3	0.8
	3.0	6.0	6.0	1.4	0.91		
	3.0	6.0	6.0	0.9	0.83		
	2.5	8.0	7.0	1.3	0.84	3.2	1.6
	2.5	7.7	7.0	1.0	0.81		
	3.0	6.0	8.0	0.6	0.80		
	3.0	5.8	8.5	0.7	0.80	1.5	1.8
	3.0	6.0	8.5	1.4	0.80		
	3.0	5.7	8.5	0.7	0.80		
	3.0	5.5	10.0	0.2	0.80	1.1	1.8
	3.0	5.5	9.0	2.3	0.78		
	3.0	5.5	9.0	-0.4	0.77		
	3.0	5.5	9.0	1.2	0.76	1.9	1.3
	1.5	7.0	6.0	2.0	0.65		
Total	45.5	96.9	118.3	158.0	124.2	8.0	7.3
Ave.	2.8	6.1	7.4	1.05	0.83	1.9	1.7

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Table No. XVI. Jersey Heifer No. 143.
Record of Weights and Nutrients Received.
Receiving Energy Sufficient to Make Normal Growth.
Average per Day by 10-Day Periods.

Age	Weight	Weight compared to normal	Dig. Crude Protein		Net Energy		Amount of Armsby's standard consumed
			Armsby's standard	Consumed	Armsby's standard	Consumed	
Days	Pounds	Per cent	Pounds	Pounds	Therms	Therms	Per cent
206	286	96.5	0.71	0.85	4.17	4.27	102.4
216	306	98.8	0.73	0.87	4.29	4.50	105.1
226	313	97.1	0.73	0.91	4.33	4.44	102.7
236	323	96.4	0.74	0.91	4.39	4.44	101.3
246	336	96.8	0.75	1.01	4.50	4.55	101.2
256	343	95.4	0.76	1.11	4.57	4.66	102.1
266	350	94.3	0.76	1.12	4.63	4.82	104.1
276	353	92.4	0.76	0.96	4.66	4.76	102.0
286	365	93.0	0.77	0.89	4.77	4.85	101.6
296	389	96.6	0.79	0.91	5.00	4.92	98.4
306	385	93.4	0.78	0.92	4.96	5.15	103.8
316	391	93.0	0.79	0.93	5.01	5.46	108.8
326	407	94.9	0.80	0.99	5.16	5.86	113.6
336	422	96.6	0.80	1.09	5.29	6.05	114.3
346	435	97.8	0.81	1.13	5.40	5.98	110.8
356	437	96.5	0.81	1.13	5.42	5.98	110.4
Total	5841	1529.5	12.36	15.79	76.61	80.78	1682.6
Ave.	365	95.6	0.77	0.98	4.78	5.04	105.2

Table No. XVII. Jersey Heifer No. 143.
FeedConsumed and Gain in Weight and Height.
Receiving Energy Sufficient to Make Normal Growth.

Weight by 10-Day Periods and Height
by 30-Day Periods.

	Grain mixture	Alfalfa hay	Corn Silage	Gain in Weight		Gain in Height	
				Actual	Normal	Actual	Normal
	Pounds	Pounds	Pounds	Pounds	Pounds	Centimeters	Centimeters
	3.5	4.0	0.5				
	3.5	4.0	2.0	2.0	1.22		
	3.0	5.0	2.0	0.7	1.27	0.03	1.3
	3.0	5.0	2.0	1.0	1.26		
	2.5	6.5	2.0	1.3	1.23		
	2.0	8.0	2.0	0.7	1.20	3.8	2.0
	2.0	8.0	3.0	0.7	1.20		
	2.5	5.7	5.0	0.3	1.10		
	2.5	4.8	7.5	1.2	1.03	0.4	2.5
	2.5	5.0	7.5	2.4	1.04		
	3.0	4.5	7.5	-0.4	0.91		
	3.5	4.0	8.0	0.6	0.83	2.2	1.9
	4.0	4.0	8.0	1.6	0.84		
	4.0	5.0	7.0	1.5	0.81		
	3.5	6.0	7.0	1.3	0.80	2.9	1.7
	3.5	6.0	7.0	0.2	0.80		
Total	48.5	85.5	78.0	151.0	156.4	9.33	9.4
Ave.	3.0	5.3	4.9	1.01	1.04	2.2	2.2

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Table No. XVIII. Holstein Heifer No. 360.
Record of Weights and Nutrients Received.
Receiving Energy Sufficient to Make Normal Growth.
Average per Day by 10-Day Periods.

Age	Weight	Weight compared to normal	Dig. Crude Protein		Net Energy		Amount of Armsby's standard consumed
			Armsby's standard	Consumed	Armsby's standard	Consumed	
Days	Pounds	Per cent	Pounds	Pounds	Therms	Therms	Per cent
306	600	118.4	0.85	1.27	6.80	6.03	88.7
316	603	116.8	0.85	1.17	6.82	6.07	89.0
326	621	118.2	0.85	1.38	6.96	6.45	92.6
336	627	117.2	0.85	1.48	7.01	6.74	96.2
346	639	117.4	0.85	1.50	7.11	6.95	97.7
356	659	118.9	0.85	1.64	7.27	7.07	97.3
366	662	118.0	0.85	1.57	7.29	6.87	94.2
376	683	120.6	0.85	1.37	7.46	6.79	91.0
386	682	119.3	0.85	1.43	7.45	7.24	97.2
396	715	123.8	0.85	1.43	7.69	7.24	94.3
406	695	118.7	0.85	1.43	7.56	7.24	95.9
416	737	124.3	0.85	1.27	7.82	6.50	93.1
426	739	123.3	0.85	1.35	7.83	6.22	79.4
436	745	123.2	0.85	1.17	7.87	5.01	63.7
446	753	123.5	0.85	0.92	7.91	3.85	48.7
456	748	121.0	0.85	0.81	7.88	3.40	43.2
Total	10908	1922.6	13.60	21.26	118.78	99.75	1362.2
Ave.	682	120.2	0.85	1.32	7.42	6.23	85.1

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Table No. XIX. Holstein Heifer No. 360.
Feed Consumed and Gain in Weight and Height.
Receiving Energy Sufficient to Make Normal Growth.

Weight by 10-Day Periods and Height by 30-Day Periods.

	Grain mixture Pounds	Alfalfa hay Pounds	Corn silage Pounds	Gain in Weight Actual Pounds	Gain in Weight Normal Pounds	Gain in Height Actual Centimeters	Gain in Height Normal Centimeters
	3.0	8.0	5.5				
	2.5	7.2	10.0	0.3	0.93		
	3.0	9.3	6.0	1.8	0.94	0.3	0.5
	3.0	10.0	5.7	0.6	0.95		
	3.0	10.0	7.0	1.2	0.97		
	2.5	12.0	6.0	2.0	0.96	3.7	1.4
	2.5	11.4	6.0	0.3	0.71		
	3.0	8.6	9.0	2.1	0.53		
	3.0	9.0	11.0	-0.1	0.54	1.1	1.7
	3.0	9.0	11.0	3.3	0.55		
	3.0	9.0	11.0	-2.0	0.83		
	2.5	8.0	11.0	4.2	0.74	3.2	1.7
	1.5	10.0	10.0	0.2	0.61		
	0.0	10.0	10.0	0.6	0.53		
	0.0	8.0	7.0	0.8	0.54	0.6	1.4
	0.0	7.0	7.0	-0.5	0.83		
Total	35.5	146.6	133.2	148.0	111.6	8.9	6.7
Ave.	2.2	9.1	8.3	1.0	0.74	2.1	1.5

4-22-8M

Table XX. Summary of Results.
Group Receiving Energy According to Armsby's Standard
and Group Receiving Energy Sufficient to Make Normal Growth.

Expr. animals	Age at beginning	Weight at beginning	Average daily gain	Average daily normal gain	Gain as compared to normal	Energy consumed as compared to Armsby's standard
	Days	Pounds	Pounds	Pounds	Per cent	Per cent
15	291	421	1.20	0.99	125.3	99.8
18	197	276	1.08	0.98	99.0	100.0
140	343	555	.87	0.66	131.8	94.8
142	251	337	1.16	0.90	128.9	100.7
361	270	559	1.50	0.87	172.4	99.0
Average	270	430	1.16	0.89	130.3	98.9
17	236	367	1.29	1.00	129.0	94.0
141	276	402	1.05	0.83	132.0	96.1
143	206	286	1.01	1.04	105.8	105.2
360	306	600	1.00	0.74	135.1	85.1
Average	256	414	1.08	0.89	125.5	95.1

(17) ✓

557	481.1
367	331.7
190	149.4 ✓

(141) ✓

560	506.4
402	382.2
158	124.2

(143) ✓

437	452.8
286	296.4
151	156.4 ✓

(360) ✓

748	618.2
600	506.6
148	111.6

Total 647

Av. 1.08

Total 541.6

Av. .90

(15)

601
421
180

542.8
394.0
148.8

(18)

439
276
163

4
443.
296.
147.

(140)

685
553
130

541.7
442.4
99.3

(142)

511
337
174

488.
352.
136.

(361)

784
539
225

596.0
466.0
130.0

Total
872
ave 1.16

Total 661.5
ave .88

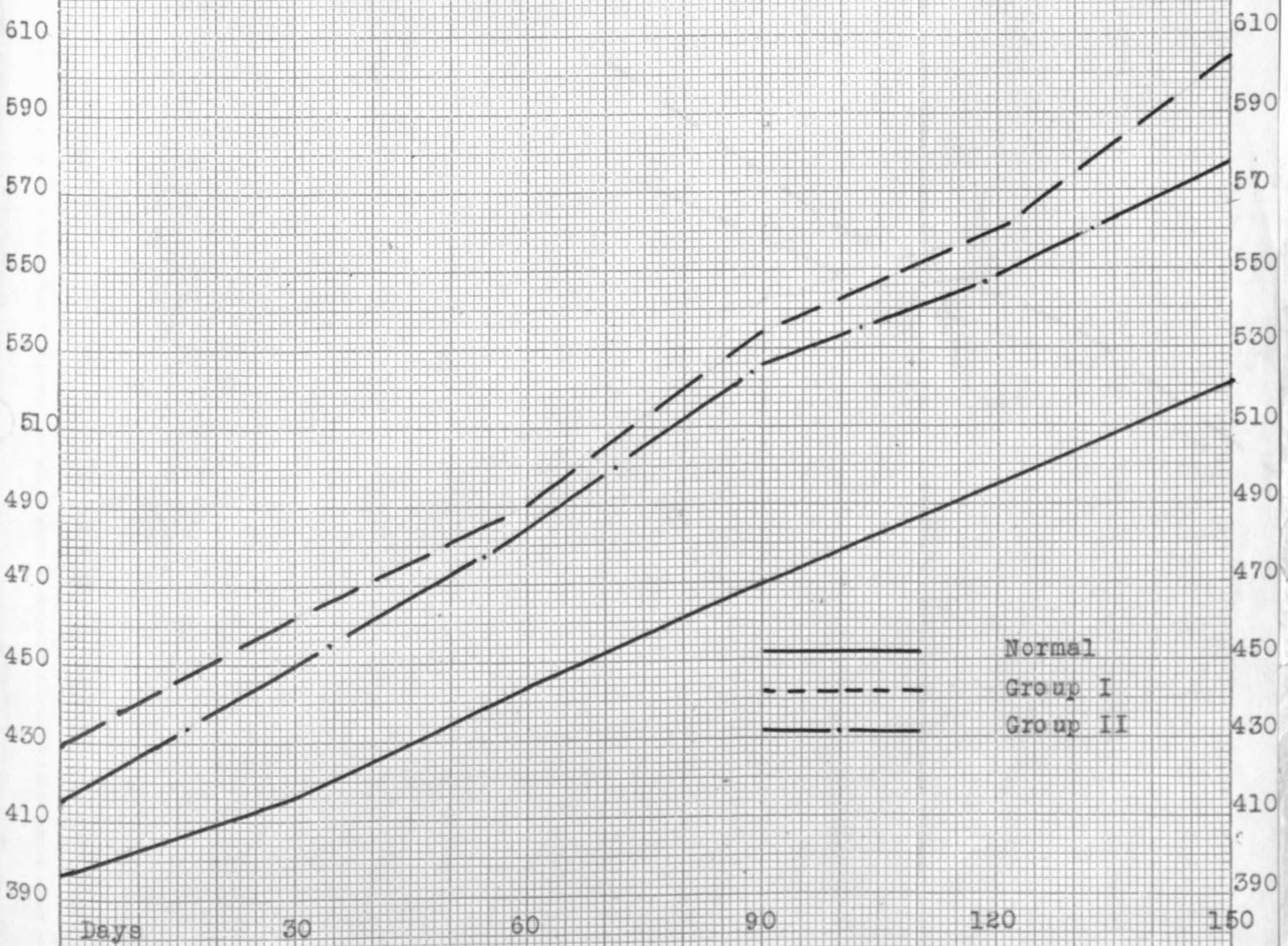
Table XXI. Summary of Results.
Group Receiving Energy According to Armsby's Standard
and Group Receiving Energy Sufficient to Make Normal Growth

Expr. animals	Age at beginn-ing	Height at beginn-ing	Average gain per 30 days	Average normal gain per 30 days	Gain as compared to normal	Energy con-sumed as compared to Armsby's standard
	Days	Cm.	Cm.	Cm.	Per cent	Per cent
15	291	103.1	1.9	1.5	126.7	99.8
18	197	94.4	2.8	1.8	157.8	100.0
140	343	108.6	1.4	1.3	107.7	94.8
142	251	101.5	2.1	1.9	109.8	100.7
361	270	110.0	2.1	1.6	131.3	99.0
Average	270	103.5	2.2	1.6	126.7	98.9
17	236	97.4	2.7	1.7	156.0	94.0
141	276	103.1	1.9	1.7	109.6	96.1
143	206	95.8	2.2	2.2	100.0	105.2
360	306	111.5	2.1	1.5	132.8	85.1
Average	256	102.2	2.2	1.4	124.6	95.1

Comparison of Growth by Groups.

Group I Receiving Energy According to Armsby's Standard.

Group II Receiving Energy Sufficient to Make Normal Growth.



The average for both groups combined shows that the three Ayrshire heifers consumed 96.9% of Armsby's standard and made a gain of 120.7% as compared to normal. The four Jerseys consumed 99.3% of Armsby's energy requirements and made a gain of 125.7% as compared to normal. The two Holsteins consumed 92.9% of Armsby's standard and made a gain of 135.7% as compared to normal.

No definite conclusions can be drawn from this data because a fair study as to the relation of breed to gain in weight as compared to energy consumed would have to include not only a large number of animals of each breed, but they would also have to be of approximately the same age.

Relation of Age to Gain in Weight and Height. Table XXIII gives data showing the relation between age and gain in weight and height. The 16 calves in the yeast experiment are also included in this table. The data shows that the 16 calves were 22 days old, consumed 109.7% of Armsby's standard and made a gain of 106.8% as compared to normal. The two heifers 6 months of age at the beginning of the experiment consumed 102.6% of Armsby's energy requirements and made a gain of 102.4% as compared to normal. The heifer begun at 7 months of age consumed 94% of Armsby's standard and made a gain of 129.0% as compared to normal.

The table further shows that from then on the animals consuming a little less than 100% of Armsby's standard made a gain of from 128 to 143% as compared to normal. The point to be emphasized here is that the data, limited in quantity as it is, nevertheless shows that energy requirements as set forth in Armsby's standard for growing dairy heifers seem to be correct with animals up to the age of about 7 months and from then on it appears to be too high.

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Table XXII. Relation of Breed to Gain in Weight and Height.

Group I Receiving Energy According to Armsby's Standard,
Group II Receiving Energy Sufficient to Make Normal Growth.

	Breed	Number of animals	Gain in weight per day	Gain as compared to normal	Gain in height per 30 days	Gain as compared to normal	Energy consumed compared to Armsby's standard
			Pounds	Per cent	Cm.	Per cent	Per cent
Group I	Ayrshire	2	1.14	112.3	2.3	142.3	99.9
	Jersey	2	1.01	130.4	1.8	108.8	97.8
	Holstein	1	1.50	172.4	2.1	131.3	99.0
Group II	Ayrshire	1	1.29	129.0	2.7	156.0	94.0
	Jersey	2	1.07	118.9	2.1	104.8	100.7
	Holstein	1	1.00	135.1	1.5	132.8	85.1
Ave. of Group I and Group II	Ayrshire	3	1.21	120.7	2.5	149.1	96.9
	Jersey	4	1.04	125.7	2.0	106.8	99.3
	Holstein	2	1.25	153.8	1.8	135.7	92.9

Table XXIII. Relation of Age to Gain in Weight and Height.

Age at beginning	Experimental animals	Gain in weight compared to normal	Gain in height compared to normal	Energy consumed compared to Armsby's standard
Months	Number	Per cent	Per cent	Per cent
Less than 1	16	106.8	.....	109.7
6	2	102.4	128.9	102.6
7	1	129.0	156.0	94.0
8	1	128.0	109.8	100.7
9	3	143.2	122.5	98.3
10	1	135.1	132.8	85.1
11	1	131.8	107.7	94.8

CONCLUSIONS.

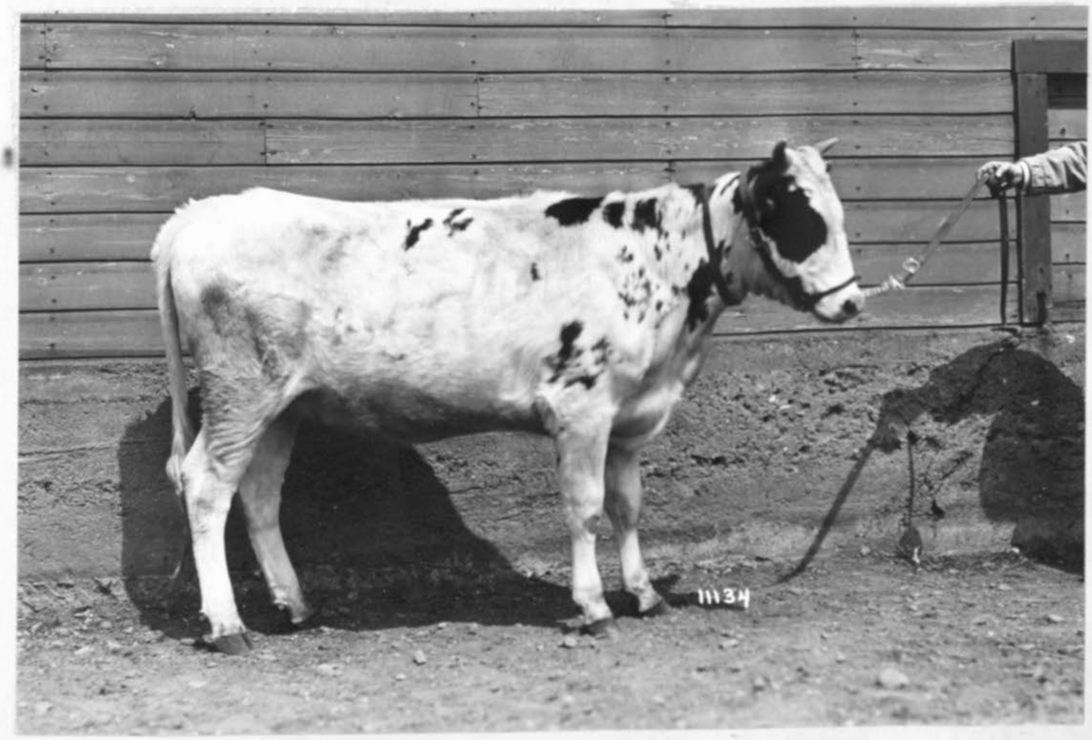
1. The results of recent investigations show that Armsby's energy requirements, while apparently nearly correct for young calves up to the age of six months, are nevertheless too high for heifers above that age.

2. The data collected in this investigation indicate that for heifers over six months of age the energy requirements as set forth in Armsby's standard are about 30% too high.

3. The number of animals used in this experiment was too small to warrant a conclusion as to the relation of breed to gain in weight and also as to the relation between age, month by month, and the energy necessary to make normal growth.

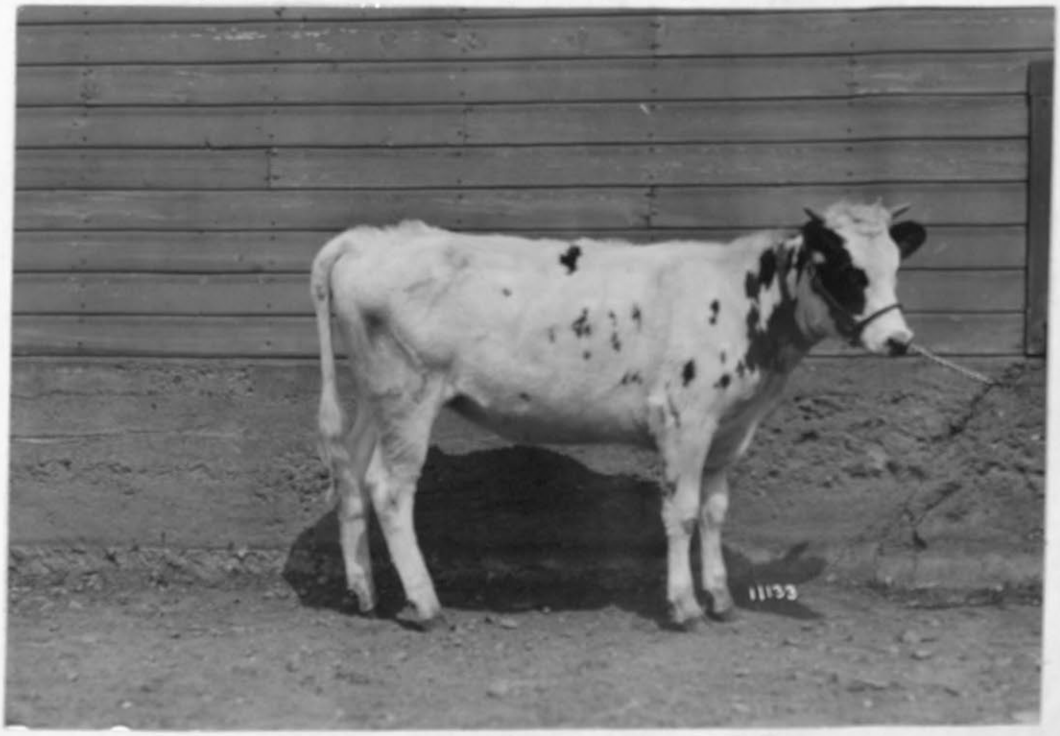
4. The ultimate solution of this problem will have to include data of a comparatively large number of heifers of the different dairy breeds taken at different ages.

Heifer 15.
At Close of Experiment.
Energy Consumed 99.8% of Armsby's Standard.



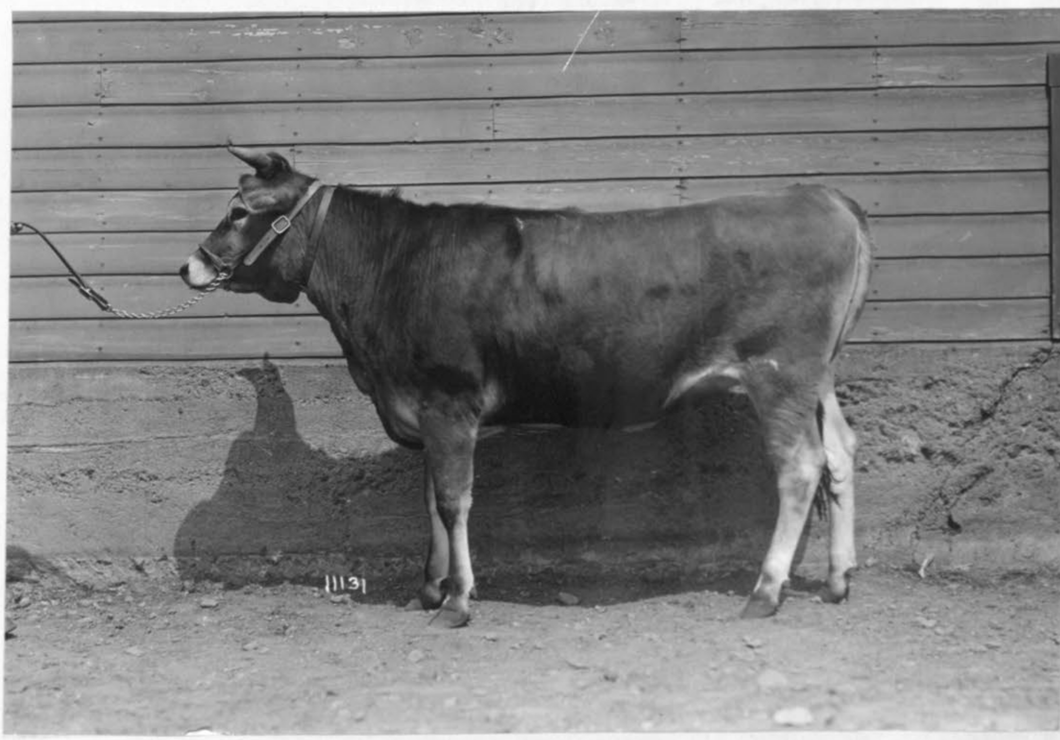
Age at Beginning of Experiment, 291 Days,
Weight at Close of Experiment, 601 Pounds,
Average Daily Gain, 1.24 Pounds (125.3% of Normal).

Heifer 18.
At Close of Experiment.
Energy Consumed 100.0% of Armsby's Standard.



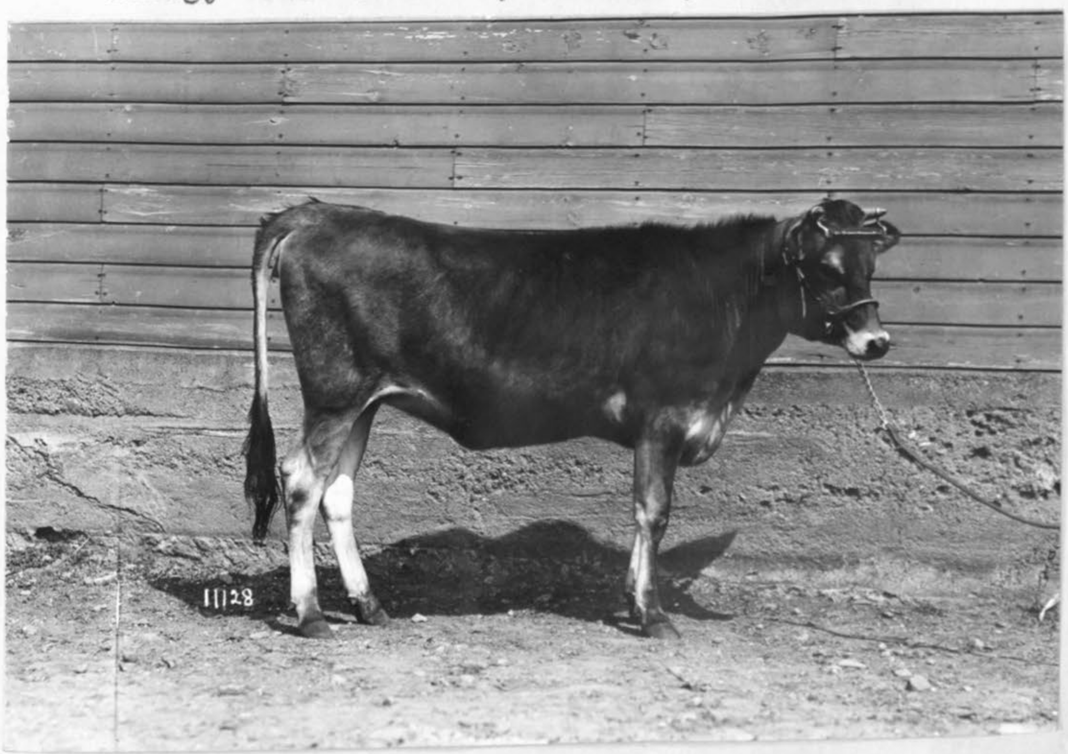
Age at Beginning of Experiment, 197 Days,
Weight at Close of Experiment, 439 Pounds,
Average Daily Gain, 1.04 Pounds (99.0% of Normal)

Heifer 140.
At Close of Experiment.
Energy Consumed 94.8% of Armsby's Standard.



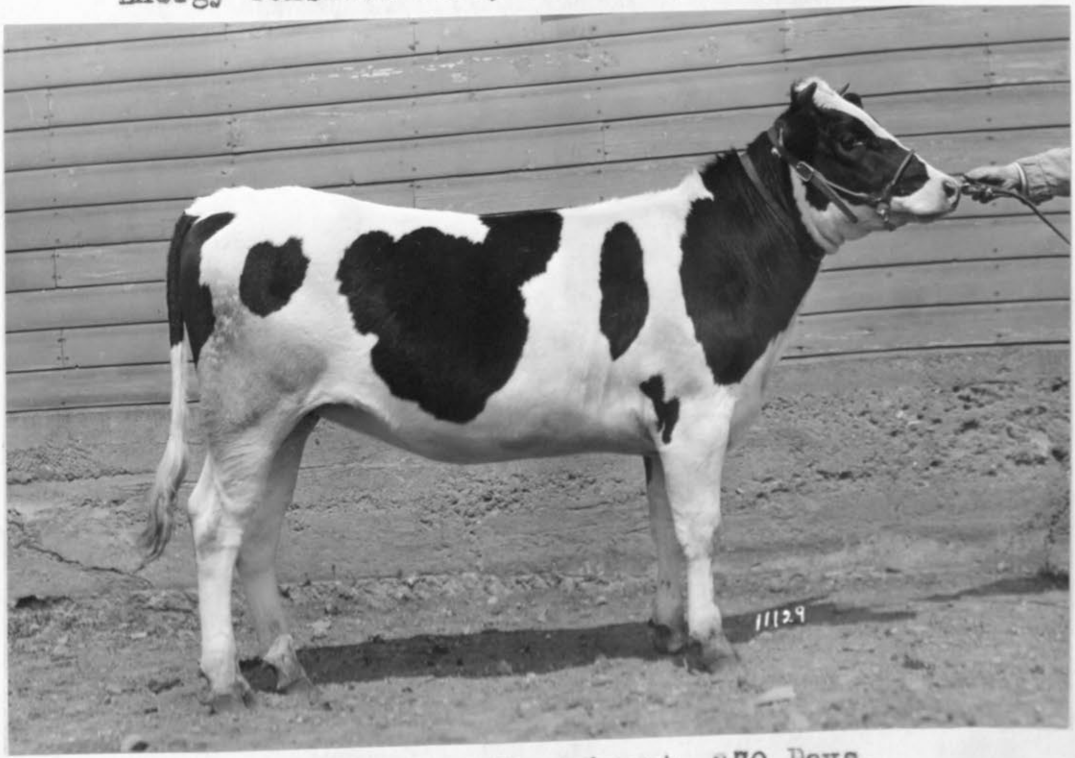
Age at Beginning of Experiment, 343 Days,
Weight at Close of Experiment, 685 Pounds,
Average Daily Gain, 0.87 Pounds (131.8% of Normal).

Heifer 142.
At Close of Experiment.
Energy Consumed 100.7% of Armsby's Standard.



Age at Beginning of Experiment, 251 Days,
Weight at Close of Experiment, 511 Pounds,
Average Daily Gain, 1.16 Pounds (128.9% of Normal).

Heifer 361.
At Close of Experiment.
Energy Consumed 99.0% of Armsby's Standard.



Age at Beginning of Experiment, 270 Days,
Weight at Close of Experiment, 784 Pounds,
Average Daily Gain, 1.50 Pounds (172.4% of Normal).

Heifer 17.
At Close of Experiment.
Energy Consumed 94.0% of Armsby's Standard.

Age at Beginning of Experiment, 236 Days,
Weight at Close of Experiment, 557 Pounds,
Average Daily Gain, 1.29 Pounds (129.0% of Normal).

Heifer 141.
At Close of Experiment.
Energy Consumed 96.1% of Armsby's Standard.

Age at Beginning of Experiment, 276 Days,
Weight at Close of Experiment, 560 Pounds,
Average Daily Gain, 1.03 Pounds (132.0% of Normal).

Heifer 143.
At Close of Experiment.
Energy Consumed 105.2% of Armsby's Standard.

Age at Beginning of Experiment, 206 Days,
Weight at Close of Experiment, 437 Pounds,
Average Daily Gain, 1.10 Pounds (105.8% of Normal).

Heifer 360.
At Close of Experiment.
Energy Consumed 85.1% of Armsby's Standard.

Age at Beginning of Experiment, 306 Days,
Weight at Close of Experiment, 748 Pounds,
Average Daily Gain, 1.00 Pound (135.1% of Normal).

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