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ECONOMY IN FEEDING THE FAMILY

THE FOOD VALUE OF MILK

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The Bulletins of this Station are mailed free to citizens of Connecticut who apply for them, and to others as far as the editions permit.

THE FOOD VALUE OF MILK

At the annual meeting of the Connecticut Dairymen's Association in January, 1919, Miss Edna L. Ferry of this Station gave an address with the above title.

"At the conclusion of Miss Ferry's address it was voted to ask the Experiment Station to prepare a bulletin on the food value of milk which could be distributed among consumers."

In response to the request this bulletin has been prepared, which is largely a transcript of Miss Ferry's paper. Her untimely death has put on others the work of editing it which has consisted chiefly in slight changes in form and arrangement.

INTRODUCTION.

Milk is the only food that supplies all of the food elements which the new-born animal must have in order to live and grow.

Among wandering Indian tribes the child whose mother fails to nurse it is doomed to die because no other milk can be had.

In countries where milch animals are scarce, as in Japan and China, mothers from necessity, if not from choice, nurse their children for relatively long periods, sometimes for two and even three years.

In countries where dairy cattle are abundant the cow is the foster mother of a large part of the infant population which for one reason or another does not have its mother's milk.

The world has had no more pitiful tragedies in the present war than the starving to death—or to life-long inefficiency—of a large infant population.

Hoover, who had the best chance to observe and who is given to sober statement without exaggeration, says:

"One of the first acts of the Germans was to denude the people of Belgium to a very large extent and the north of France almost wholly of their cattle. In consequence it has been necessary to maintain a stream of condensed milk for the whole of the last four years.

"The European races are absolutely dependent for the rearing of their young on these cattle. There is no cruelty to a population greater than to rob them of their dairy stock."

The need of milk is not limited to the first year of life. When the child is able to enlarge its diet and take solid food, milk is

an indispensable adjunct. Of the 27 brands of "infant foods" in market, which were examined by this Station (Report 1915, p. 324), 16 claim to contain milk and the directions for the use of 9 others prescribe mixture with milk.

All through childhood and youth bread and milk and cereal and milk are recognized as "growing foods."

Milk, too, is the most commonly prescribed food for adults in severe illness and a resource in time of sudden exhaustion.

It is hardly too much to say that public health, content and civilization follow the cow.

The work of Dr. Osborne at this Station has largely contributed to the discovery of the reasons for this unique value of milk which are leading to a greater appreciation and more rational use of it. This work has been in a way incidental to a general study of the character and function of proteins and of the laws of nutrition. The investigations on the chemistry of the proteins have been carried on for many years by Dr. Osborne and in the nutrition studies which followed he has had the valuable coöperation of Dr. Lafayette B. Mendel of Yale University.

CONSTITUTION OF PROTEINS.

The foundation of our new knowledge regarding milk was laid by finding out and setting forth the composition and structure of a large number of different proteins, which are the flesh-growing materials of the body and an indispensable part of all the vital body fluids. This work showed for the first time their great variety and the fact that a nearly identical percentage composition of their elements (nitrogen, carbon, oxygen, hydrogen, and sometimes sulphur and phosphorus) went along with wide differences in structure and in physical and chemical properties; and that in the same food material, whether animal or vegetable, two or more proteins of quite different quality were usually found together.

Dr. Osborne's work, with that of others, showed that a protein was no such simple thing as salt or sugar, but was made up of about eighteen different complexes, knots of nitrogen-containing groups called amino-acids, each of them a complicated structure in itself.

The following table gives the names of these amino-acids, the approximate percentage of each in several of the common proteins and shows the striking differences in their amount.

Comparative composition of proteins.

AMINO-ACIDS	ZEIN (MAIZE)	GLIADIN (WHEAT)	CASEIN (MILK)	LACTAL- BUMIN (MILK)	EDESTIN (HEMP- SEED)
	<i>per cent.</i>	<i>per cent.</i>	<i>per cent.</i>	<i>per cent.</i>	<i>per cent.</i>
Glycocoll	0.00	0.00	0.00	0.00	3.80
Alanine	13.39	2.00	1.50	2.50	3.60
Valine	1.88	3.34	7.20	0.90	6.20
Leucine	19.55	6.62	9.35	19.40	14.50
Proline	9.04	13.22	6.70	4.00	4.10
Phenylalanine	6.55	2.35	3.20	2.40	3.09
Aspartic acid	1.71	0.58	1.39	1.00	4.50
Glutamic acid	26.17	43.66	15.55	10.10	18.74
Serine	1.02	0.13	0.50	?	0.33
Tyrosine	3.55	1.50	4.50	2.20	2.13
Cystine	?	0.45	?	?	1.00
Histidine	0.82	1.49	2.50	1.53	2.19
Arginine	1.55	3.16	3.81	3.01	14.17
Lysine	0.00	?	7.61	8.10	1.65
Tryptophane, about ..	0.00	1.00	1.50	+	+
Ammonia	3.64	5.22	1.61	1.32	2.28
	88.87	84.72	66.92	56.46	82.28

In view of these great differences of structure and composition of proteins, the question arose: have they nevertheless about the same food value as has been assumed, or have they not? If they have not, the principles on which our whole art of cattle feeding is founded has lost a large part of its foundation.

Clearly, the only way to settle the question was to study the feeding effect of each protein by itself on both growth, maintenance and production.

Before the work here was begun, all experimenters who endeavored to feed animals on diets composed of pure nutrients failed. Both mature and young animals promptly declined in weight on such diets. To-day we have such an understanding of the influence of food on growth that merely by changing a single constituent of the diet we can stop the growth of a young animal at any stage of development, maintain it for many months in perfect health, but without growth, and later cause it to grow

again at a normal rate to full maturity and reproduce. It is due to the use of milk in the earlier attempts in feeding animals experimentally that we owe our success in developing methods of feeding which have opened up entirely new fields for investigation.

Our first attempts to make an animal grow on a mixture of pure protein, fat, carbohydrate and inorganic salts were no more successful than those of our predecessors, but we soon found that animals which failed to thrive on our artificial diets could be restored promptly to excellent condition by giving them a mixture of dried milk, starch and lard, and that control animals fed on a similar diet from weaning grew normally to full maturity and reproduced. Although the artificial diets were almost exactly like the milk diets, in respect to the kind and proportion of the then known nutrients, the milk diet was entirely adequate as a food, whereas the artificial diet was wholly inadequate. Wherein this profound difference lay was a mystery. By a process of elimination we were forced to the conclusion that the water-soluble portion of the milk contained something which was essential for life, and later that the fat component contained something which was indispensable for long-continued growth. This discovery that milk contains two hitherto unsuspected substances, now known as the water-soluble and fat-soluble vitamins, which will be referred to later, made it possible for us to become pioneers in the study of various problems relating to growth and maintenance. The field of study thus opened has been entered by numerous investigators here and abroad with results of far-reaching importance.

The experiments here to be described were made with albino rats because these small animals are omnivorous and can be fed with such quantities of the experimental rations as we are able to prepare in the laboratory in a state of purity. To insure perfect accuracy it is necessary that these rations shall consist of ingredients which are chemically pure and to prepare such rations in quantity is very laborious and costly. The results of these experiments can be accepted as giving evidence of the true food value of milk because they are in harmony with our experience in feeding not only ourselves but also farm animals.

The question may be asked—Are the results of experiments in

feeding rats, or other of the lower animals, applicable to human beings?

While the foods suited to different species of animals may differ widely in their appearance and physical properties, the digestible nutrients contained in them are very much alike in their chemical characters, so that by the processes of digestion quite similar products result from apparently very different kinds of food. Such differences as exist are rather in proportion than in kind. Furthermore, the tissues of the different types of animals are chemically even more alike than their foods and, consequently, their nutritive requirements are in principle much more nearly the same than those unfamiliar with the chemistry of nutrition would suppose.

The conditions in feeding farm animals are necessarily so complex that it is generally impossible to recognize the influence of any individual constituent of the ration. In our experiments with rats, on the contrary, the conditions have been so simplified that definite conclusions can be drawn regarding the rôle of each factor involved. Thus, if two series of animals are fed on mixtures of protein, fat, carbohydrate and inorganic salts, which are identical except for the kind of protein used, and one series grows normally whereas the other fails to grow at all, it is obvious that the protein alone was the determining element in the food. By means of large numbers of such experiments extending over a period of several years, we have fixed the nutritive values of many proteins, several fats, the various inorganic salts and also have studied a number of combinations of natural food products both of animal and vegetable origin which are extensively used in the daily rations of man or domestic animals.

THE PROTEINS OF MILK.

Previous to 1912 a discussion of the nutritive value of any food stuff would have been confined to a consideration of the total quantities of protein, fat, carbohydrate and salts which it contained and its value as a source of energy. As a result of work which has been done at this Station, and later in other laboratories, the field for discussion has become much broader, for it has been demonstrated that the *quality* of the protein present in any food is of even more importance than the *quantity*,

and a realization of the essential rôle which the so-called vitamins play in normal nutrition has raised many more problems.

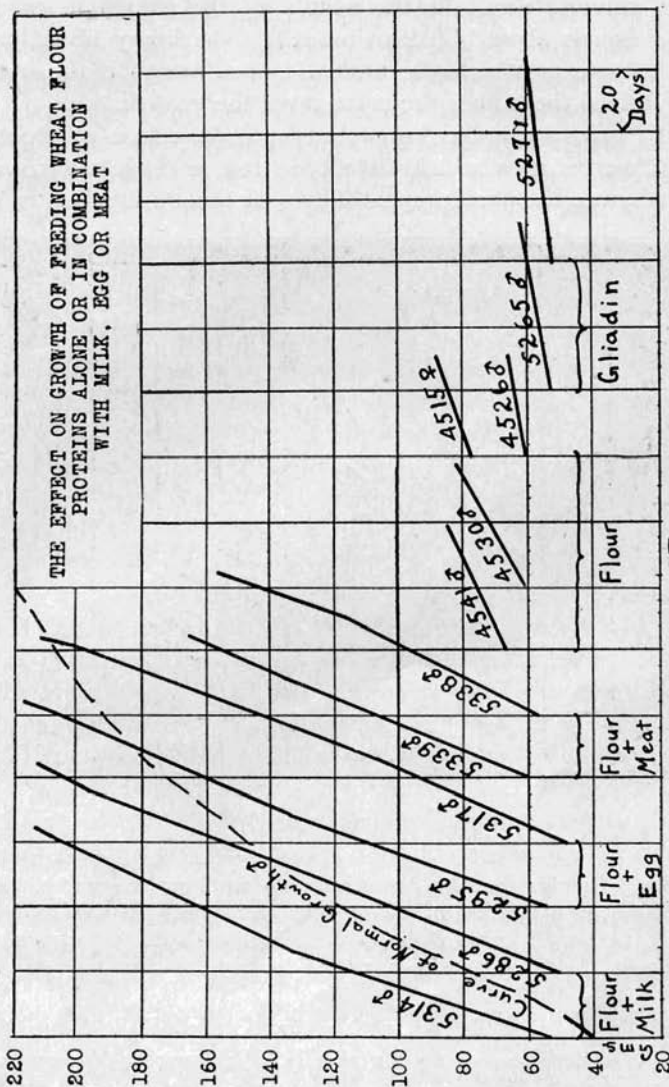
Milk contains several different proteins, but there are only two which occur in notable quantity, and these are casein, the protein found in cheese, and lactalbumin, the principal protein of whey. These two proteins differ not only in their chemical structure, but also in their nutritive value. Both suffice to promote the normal growth of young rats, but lactalbumin is somewhat more efficient for growth than is casein, for in comparable periods of time a given quantity of lactalbumin will enable an animal to gain about 33 per cent. more in weight than the same amount of casein.

This is instructive from a practical standpoint for it demonstrates that the whey, obtained as a side product from the manufacture of cheese, contains one of the most valuable food proteins known and should not be wasted. Casein, which forms about 80 per cent. of the milk proteins, is more easily digested than any other protein known and behaves in the digestive tract very much like a predigested protein. This property makes it especially desirable as a food for infants or persons with weak digestions.

For centuries people have been accustomed to use foods of animal origin with bread and other cereal products which form so large a proportion of the average dietary. Bread and milk, eggs on toast, meat sandwiches and the use of milk on breakfast cereals are just a few illustrations of this custom. If any one who was enjoying a meal of any of these mixtures were asked why he chose the combination of the animal with the vegetable product instead of eating either one alone, he would probably say that "it tasted good," or "it satisfied his appetite better that way," or something else equally indefinite. It is only recently, while engaged in investigating the nutritive value of wheat flour, that we discovered how well the proteins of milk, eggs and meat supplement the deficiencies of the wheat proteins. We now have a truly scientific reason for this universal dietary practice.

If an animal is fed on wheat flour as the sole source of protein in an otherwise adequate ration, it will grow very slowly, if at all, even when relatively large amounts of the proteins are eaten. If, however, one-third of the wheat protein is replaced by an

equivalent quantity of protein in the form of milk, eggs, or meat, the animal will grow at a practically normal rate.



To illustrate this as well as the results of our other experiments with various diets of known composition, in a condensed form, we have employed charts giving the curves of body

weight during the time of feeding. In reading these charts the squares running horizontally represent time of feeding expressed in days, running vertically the weight of the animal in grams (1 gram equals about $\frac{1}{30}$ of an ounce). The heavy black lines show the rate at which the animal gained weight; the more nearly vertical these lines the more rapid the growth.

Chart I gives a graphic representation of the curves of growth of a number of rats which have been fed in these ways, and Figure 1 gives the photographs of two of these animals.

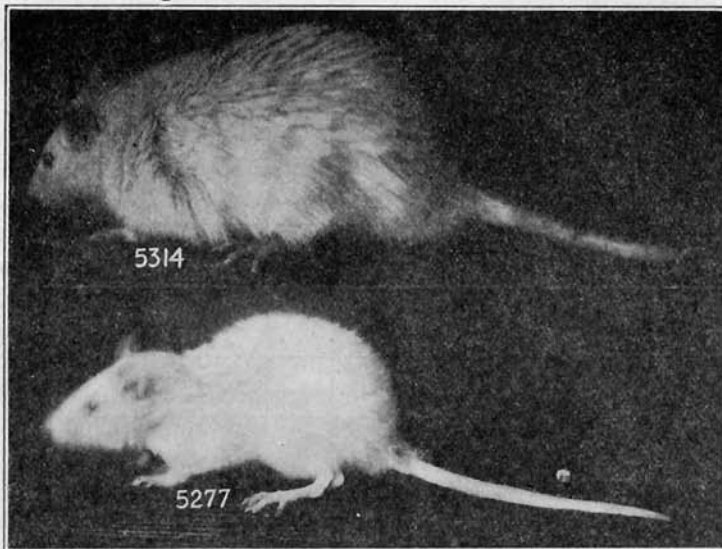


FIGURE 1

Rat 5277 was fed on a diet in which gliadin from wheat flour furnished the protein. On this food he gained only 10 grams in ten weeks. Rat 5314 was fed on a mixture of wheat flour and milk. On this food he gained 160 grams in nine weeks. This illustrates the importance of combining milk with the cereals instead of feeding the cereals alone.

All of the animals shown in this chart were of the same size and age, and were growing vigorously when put on the experimental diets. The differences in size at the end of each experiment are due solely to the protein of the diet. In this series of experiments the percentage of protein and nutritive ratio of the mixtures were practically identical, the foods differing only in

the kind of protein. The animals in the group labelled "flour" received all of their protein from wheat flour, those in the groups labelled "flour + milk," "flour + egg," and "flour + meat" received a diet whose concentration of protein was the same as that of the "flour" group, but one-third of the protein was furnished by milk, egg, or meat respectively, the remaining two-thirds being furnished by flour. It is obvious that relatively small quantities of these animal proteins greatly improved the value of the food for growth. The value of these animal products lies in the fact that they are chemically so constituted as to supplement the chemical deficiencies of the flour proteins. To those who are unfamiliar with the chemistry of proteins this may seem mysterious and confusing, hence a few words of explanation are necessary.

By digestion the proteins are broken up into the amino-acids already mentioned on page 5, which are then used in constructing the new proteins of the tissues of the growing animal. Unless the food protein furnishes a sufficient amount of each of these amino-acids which are needed to make the tissues required for normal growth the animal grows correspondingly slower than it would if more of the needed amino-acid were available.

Wheat flour contains two proteins, one of which, called gliadin, yields only a very small amount of the amino-acid called lysine. The effect of a limited supply of lysine on growth is illustrated by rats 5277 and 5265, whose curves of body weight are shown in Chart 1. These were fed on a diet in which all of the protein was furnished by gliadin. They have been maintained in good health, but have gained only about 10 grams.

The rats on the "flour" diets grew somewhat more than those on the gliadin food because flour contains another protein which yields more lysine than does gliadin and hence supplements to some extent this deficiency of the gliadin. However, the amount of lysine thus supplied was too little to promote normal growth. In this connection it is interesting to note how perfectly a young animal can be maintained in health, but without growing even for a very long time when its diet is adequate in respect to everything except the chemical constitution of its food protein. Such animals can be thus kept as infants for indefinite periods.

Chart II shows how little growth was made during nine months on a diet in which gliadin from wheat flour furnished all the protein. At the end of these nine months the rat was given a similar diet containing enough dried milk to replace the gliadin,

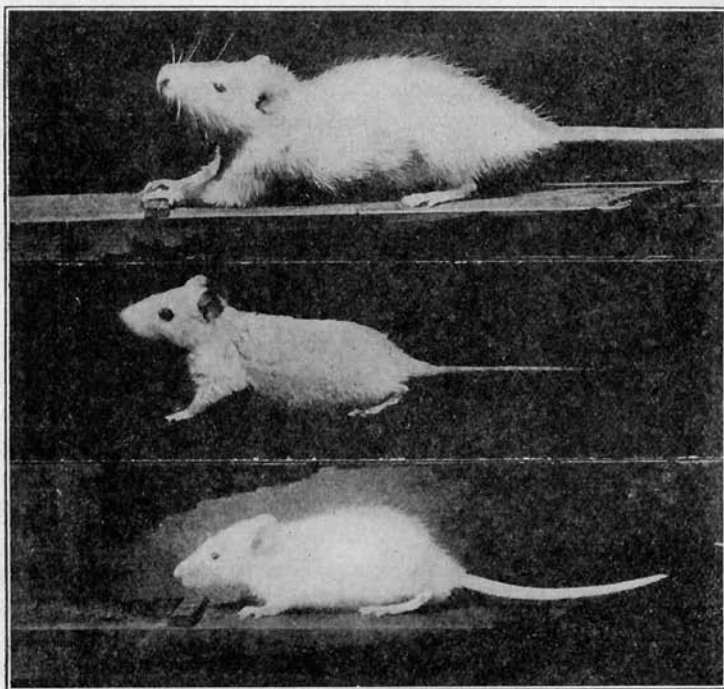
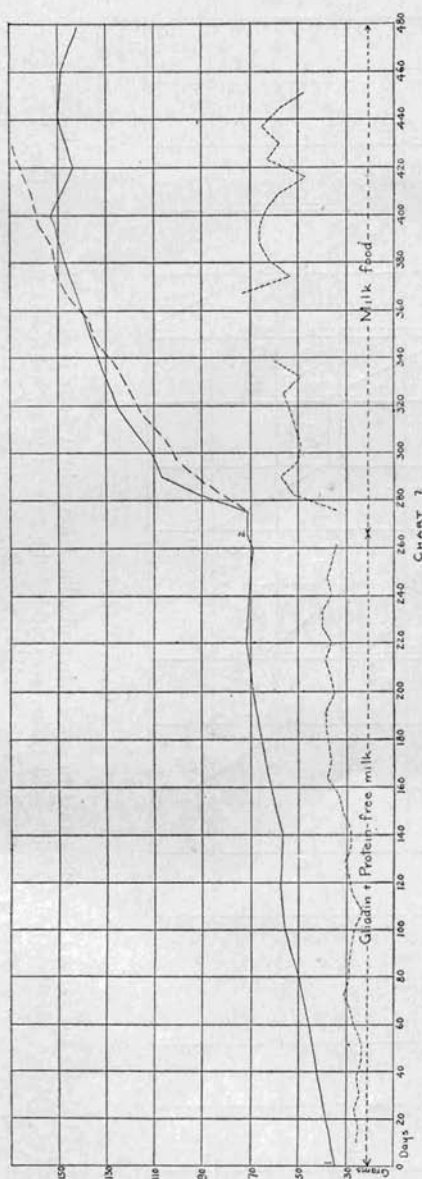


FIGURE 2

Figure 2 shows the contrast between feeding a good or a bad protein to a young rat. The two upper rats are five months old and have been fed on diets exactly alike except the one at the top had casein from milk on which it grew normally, and the one in the middle had gliadin from wheat flour on which it could not grow at all, so that when it was five months old it weighed exactly the same as the rat at the bottom which was only one month old.

and in two weeks on that food it gained as much in body weight as it had during the preceding nine months. It continued to grow normally on the milk diet to full adult size; a striking illustration of the value of milk proteins for growth. If, instead



of replacing the gliadin with milk, we had added to the gliadin food a small amount of lysine, the effect would have been the same.

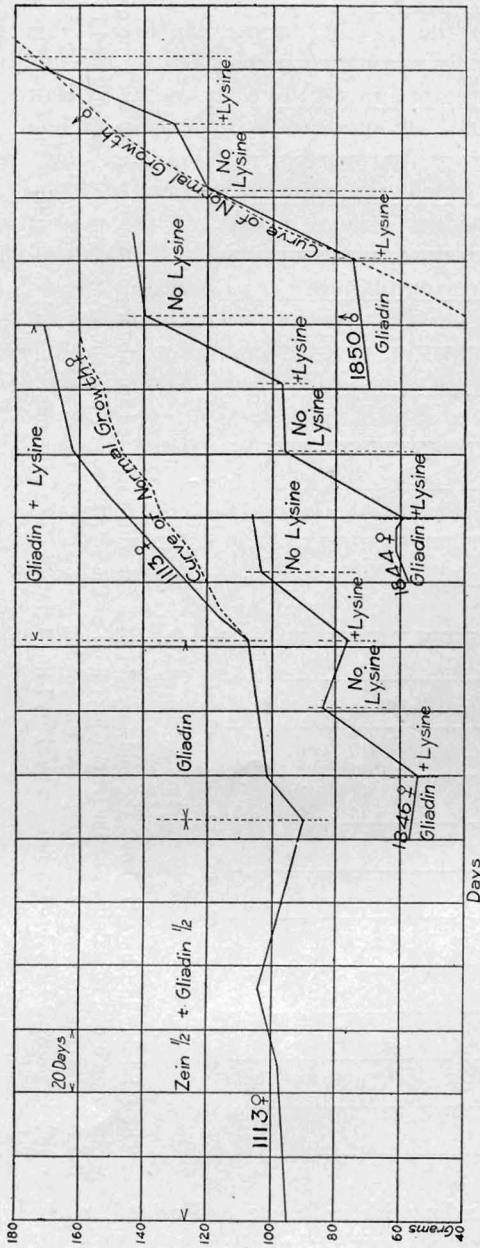


CHART III.

Chart III shows the failure of young rats to grow when gliadin from wheat flour is the sole source of the protein in the diet. When a little of the amino-acid lysine was added the rate of growth became normal. Cereal proteins yield little lysine, milk proteins yield much. This explains why combinations of cereals with milk are superior to cereals alone as food for the young.

Chart III shows the weight curves of several rats whose growth was alternately stimulated or checked by the addition to a gliadin diet of very small quantities of lysine or by its removal.

In every day practice, however, it is impossible to feed lysine, as such, and therefore the problem resolves itself into finding available proteins which are sufficiently rich in lysine to be capable of supplementing this deficiency of the flour proteins. The two foods which thus far have proved to be the most efficient supplements to flour are milk and eggs; either of these is somewhat better than meat. Thus under similar conditions of feeding when the food contains two parts of flour proteins to one part of meat protein rats gain about three times as much per unit of protein eaten as when flour furnishes all the protein, and nearly four times as much when milk or eggs are used as supplements.

The same is true for corn supplements. Zein, the principal protein of corn, lacks two essential amino-acids, tryptophane and lysine, hence when zein furnishes all of the protein of the diet, the animal loses weight rapidly and dies almost as soon as if no food were eaten. When a small quantity of one of these missing amino-acids, tryptophane, is added to the zein diet, the animal maintains its weight and lives for a long time but does not grow. If in addition to tryptophane, lysine also is added, the animal grows.

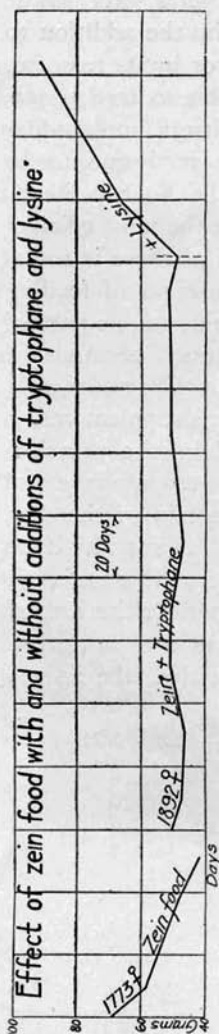


CHART IV.

Chart IV shows the important part played by amino-acids in nutrition. Zein, which forms about one-half the protein of corn meal, lacks two of these, known as tryptophane and lysine. Unless tryptophane is added to a diet containing zein as its sole source of protein, life cannot long be maintained. Unless lysine is also added, growth is impossible. The proteins of milk contain an abundance of both of these amino-acids.

Chart IV shows the curves of body weight of rats receiving zein alone as well as zein in combination with tryptophane or with tryptophane and lysine. Note that the body weight of one of these rats remained constant for six months when the diet contained zein and tryptophane. When small amounts of both lysine and tryptophane were added to the zein food the rat grew.

Figure 3 shows in a striking manner how essential it is to supply the young animal with protein which furnishes sufficient lysine. The lower picture is that of a young rat which lived for seven months in perfect health on a food containing zein + tryptophane as its sole protein. During all of this time it failed to grow and weighed only 70 grams. It did not even show signs

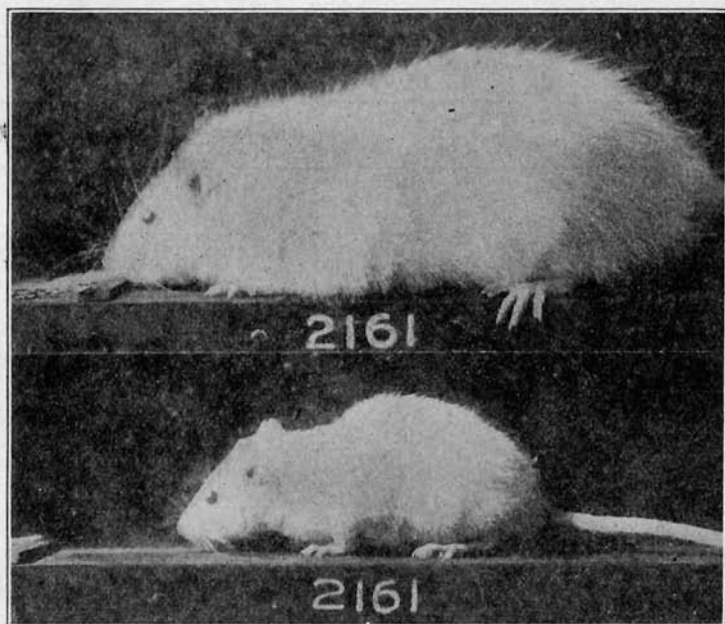


FIGURE 3.

The lower photograph is that of a rat which has been fed for seven months on a diet containing zein (one of the proteins from corn) + a small amount of amino-acid tryptophane. On this diet the rat could live but could not grow. The upper photograph is one of the same animal taken a few months later, after casein from milk had replaced the zein and tryptophane.

of maturing for, as you can see, it looks exactly like a recently weaned rat; it has remained a baby. At the end of seven months casein was used to replace the zein + tryptophane. No other change was made in the diet. During the next three months it grew at the normal rate to 230 grams, and as the upper picture shows, became a fine, vigorous animal.

What this means might be illustrated in this way. For about one-fifth of its life period the rat did not grow. Calling a man's span of life seventy years the case would be somewhat like that of a boy, kept as a healthy infant in arms until fourteen years old—weighing perhaps sixteen to twenty pounds—and who, by a change of diet when fourteen years old, attained a man's size and weight at the age of twenty-one.

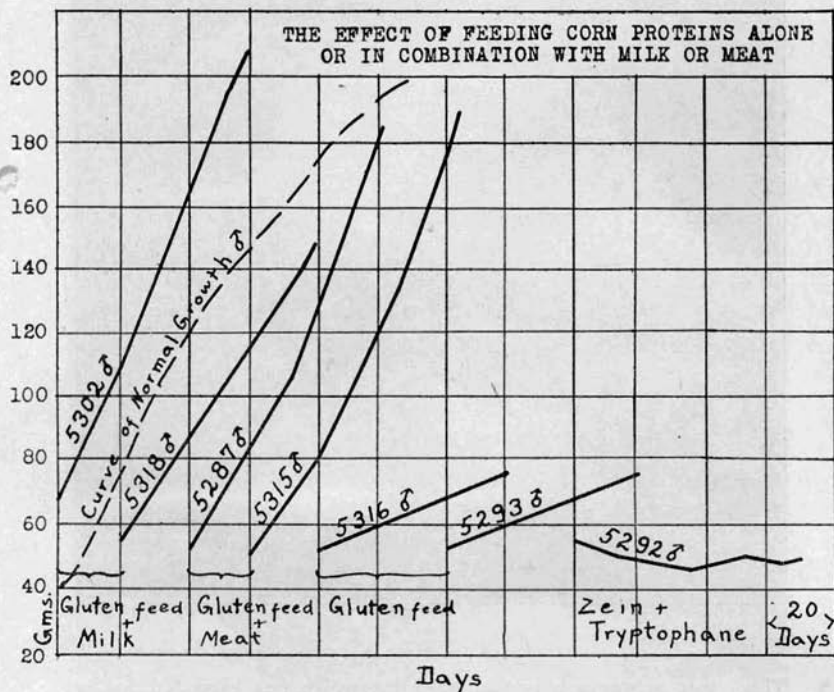


CHART V.

Two of the rats, 5293 and 5316, whose curves of body weight are shown in Chart V, had a ration in which the protein was furnished by gluten feed. Rats 5302, 5318, 5287 and 5315 on the other hand had two-thirds of their protein in the form of gluten feed and the other third as milk or meat. The nutritive ratios of all of these three foods were alike, but the results were strikingly different.

This juggling with proteins and amino-acids is very interesting to the chemist and physiologist for it represents a triumph of science which excites the wonder of those who appreciate the

almost insurmountable difficulties encountered in these investigations. It would be of little use to discuss it here, if these facts could not be applied to the feeding problems of the household and farm. Amino-acids are not commercially obtainable but products are at hand which contain proteins which furnish these

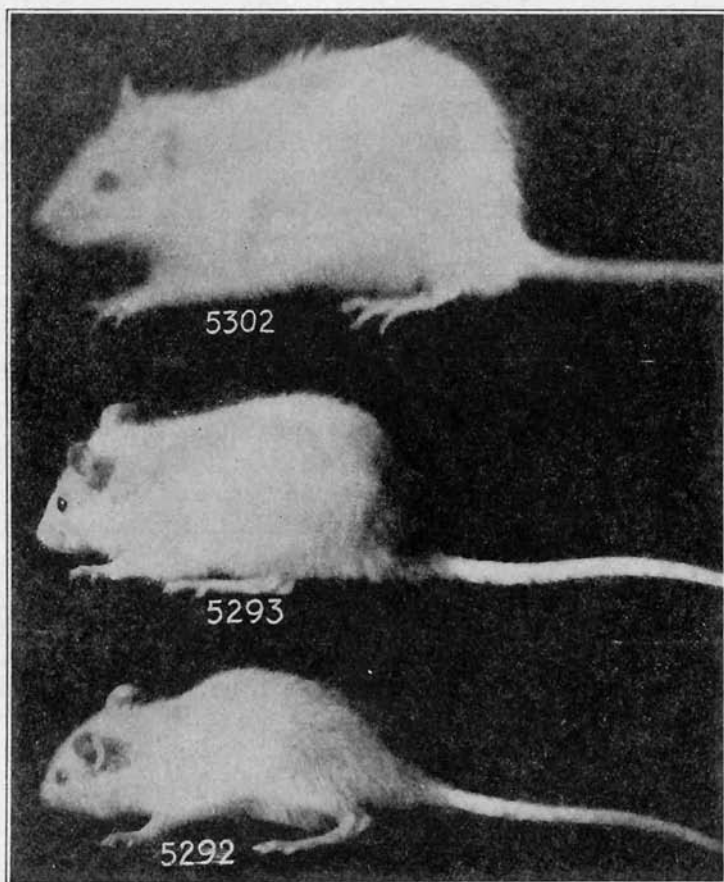


FIGURE 4

Figure 4 shows photographs of some of the animals whose curves of body weight are shown in Chart V. Although all three were of the same age, Rat 5302 which had received a mixture of gluten feed and milk is nearly three times as large as 5293 which received the gluten feed alone and more than four times as large as 5292 which was fed on zein plus tryptophane.

amino-acids in readily obtainable form. Now let us see how we can apply these facts.

When corn as a whole is fed, the other proteins in this seed supplement the zein to such an extent that the animal can grow slowly, but if the corn is combined with milk, the proteins of which are rich in both tryptophane and lycine, growth is very rapid.

Thus it appears that the chemical constitution of the protein of the food influences growth and that it is absolutely necessary to provide animals with protein of the right kind, if they are to grow well. This applies not only to growth, but also to milk or egg production. Both milk and eggs are rich in protein. The animals producing them need large amounts of protein in their food, but until the differences in the chemical constitution of the proteins of different feeds were discovered, it was not appreciated how important it is to provide protein of the right kind. This fact has been unconsciously recognized by milk producers for they always feed protein from several sources. This practice is an attempt to furnish a mixture of proteins which will mutually supplement each other, but whether the mixtures now in general use are yielding the best results at the least cost remains to be determined. As yet we do not know the actual protein requirements of milk production. Are these similar to those of growth? This problem remains for future study.

That a proper combination of proteins may mean much in the way of profits when growing animals are fed is illustrated by the following from a bulletin recently issued by the Ohio Agricultural Experiment Station. In a series of experiments, comparing the value of corn alone with combinations of corn and tankage, or corn and skim milk, it was shown that a bushel of corn fed alone produced only nine pounds of gain. The same quantity of corn fed in combination with 5.5 pounds of tankage produced 13.3 pounds of gain, and corn fed with 168 pounds of skim milk, equal to 17 pounds of dry food, increased the gain to 21.8 pounds per bushel of corn fed. In other words, each ten pounds of the dry matter in the skim milk replaced 54.9 pounds of corn. Expressing these results in terms of dollars and cents, corn alone produced pork at a loss of \$8.38 per 100 pounds of gain, whereas nine parts of corn fed with one part of tankage produced pork at a profit of \$14.91 per 100 pounds of gain, and

one part of corn fed with three parts of skim milk yielded a profit of \$35.59 per 100 pounds of gain.

THE VITAMINES OF MILK.

Another constituent of milk which has a unique value in the dietary is the butter fat. If a young rat is fed on a ration adequate in all respects except that the fat is furnished by lard, or vegetable oils like olive oil, it will grow normally for a period of about 80 days, then suddenly it declines in weight and soon

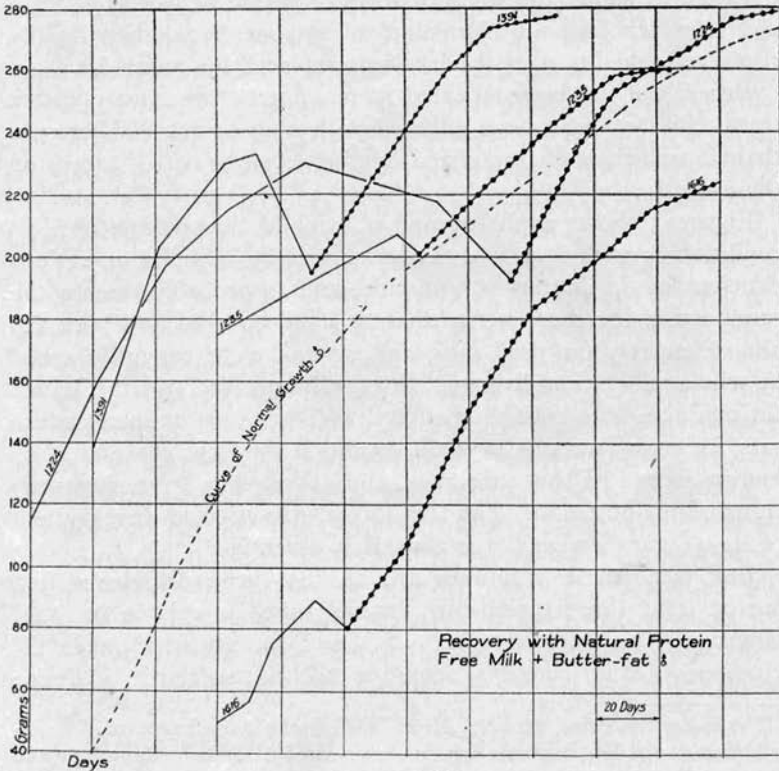


CHART VI.

Chart VI shows that butter fat contains something essential for normal growth. These curves show that after feeding a diet of purified food-stuffs, the fat being lard, the animals after growing normally for several weeks suddenly began to lose weight. When a part of the lard was replaced by butter fat (shown by the beaded line), they immediately recovered. These animals would have died in a few days if this change had not been made.

dies. Such animals frequently suffer from sore eyes and in many cases develop large ulcers on the eyeball. A small amount of butter fat added to the diet causes an immediate recovery of health, gain in weight and prompt restoration of the eyes to their normal condition. This marvellous effect is due to the presence in the butter fat of something of, as yet, unknown nature, which for the time being is called the fat-soluble vitamine. The presence or absence of this substance in any foodstuff can be detected only by feeding young animals.

Chart VI shows the weight curves of rats which declined on a diet in which lard was the sole fat component and then rapidly recovered when part of the lard was replaced by butter fat.

Recently it has been reported from some parts of Europe that many children have been afflicted with a disease called xerophthalmia, which is characterized by the development of ulcers on the eyeball.

Figure 5 shows a photograph of a child thus affected. This condition is strikingly like that exhibited by rats fed on rations deficient in the butter-fat vitamine, and is probably due to the same cause, for these xerophthalmic children who had been fed almost entirely on skim milk and cereals were promptly cured by whole milk or cod liver oil. It is still unproved that this butter fat vitamine is essential for adults. We have maintained mature rats for many months in good condition on diets containing no known source of this substance, and as yet they have shown no signs of malnutrition. For the normal growth and development of the young, however, it is absolutely essential.*

Just what these vitamines are has not been discovered yet, but at least three types exist, namely the fat-soluble or "A" vitamine; the water-soluble, "B," and the antiscorbutic, "C" vitamine. Milk contains some of the antiscorbutic vitamine

* It is worth noting that Dr. H. C. Wells, who had charge of the distribution of food in Rumania for the American Red Cross, tells us he made successful application of our observation that cod liver oil contains much of the fat-soluble vitamine.

A cargo of cod liver oil at Archangel having been offered to him he immediately ordered it sent to Rumania hoping by its use to save the eyesight of thousands of children whose eyes were in the same condition as those of rats fed on a diet deficient in the fat-soluble vitamine. By giving this cod liver oil to these children a large majority were saved from permanent blindness, even after their eyeballs had become entirely opaque.

which prevents scurvy, though less than do some of the vegetable and fruit juices, notably orange juice. This vitamine is sensitive to heat, hence children fed on pasteurized or boiled milk are more susceptible to infantile scurvy than are those fed on unheated milk, unless the scurvy-preventing vitamine is given them in some fruit or vegetable juice in which it is abundant.

The relation of the fat-soluble vitamine to nutrition, and its presence in butter fat have already been discussed at considerable



FIGURE 5

This child was fed on skim milk, and as a result an ulcer developed on one eyeball. This was because it did not get any of the so-called fat-soluble vitamine which is present in the butter fat. Plenty of cream, butter, or cod liver oil will cure this child's eye. Young rats develop this same disease when fed on diets free from the fat-soluble vitamine and are promptly cured by adding a little butter to their diet. (Photograph from Bloch, C. E., *Ugeskrift for Laeger*, Mar. 8, 1917, **79**, 309, 349.)

length. It is only necessary to add that this vitamine is quite resistant to heat, for we have passed live steam through melted butter fat for two and one-half hours without destroying its potency.

The third type of vitamine, known as the water-soluble vitamine, is also present in milk. Without an adequate supply of

this food accessory in the diet, life cannot be maintained. An animal which is fed on a ration containing no known source of this vitamine dies within a short time. If, however, when apparently dying, a very little of this food accessory is given, it recovers with surprising rapidity. This may be given in the form of milk, yeast, commercial wheat embryo, or any other natural foodstuffs.

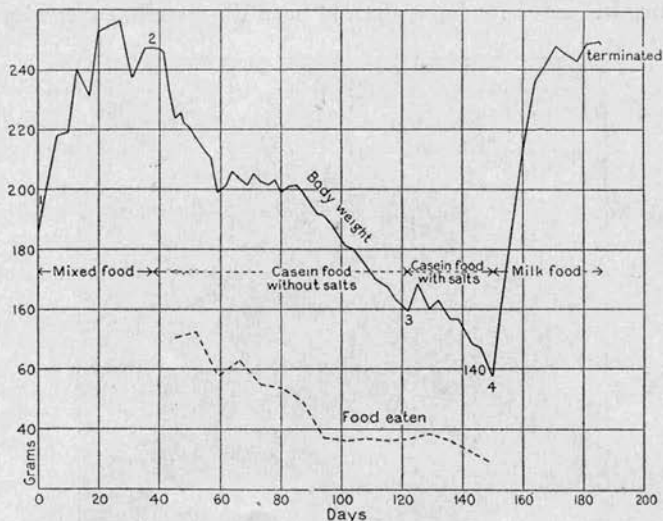


CHART VII.

Chart VII illustrates the typical recovery (in Period 4) of a rat which had declined on a diet lacking the so-called water-soluble vitamine (Periods 2 and 3), when the animal was given milk which contains this vitamine. This rat would have been dead in a few days if the milk had not been given.

Chart VII shows the rapid decline in weight typical of feeding a food deficient in the water-soluble vitamine. It also shows the effect of feeding an abundance of dried milk as a source of this vitamine.

That the water-soluble vitamine is something apart from and independent of the fat or protein of the milk is shown by the results of our experiments. For many years we used the product obtained by evaporating to dryness milk freed from fat and protein as a source of the water-soluble vitamine in the diets fed to our experimental animals.

Chart VIII shows that this product which we have called "protein-free milk" is just as efficient as a source of water-soluble vitamine as is the whole milk. Contrary to what appears to be generally believed, the water-soluble vitamine is resistant to heat. "Protein-free milk" prepared by evaporating at a temperature not far below that of boiling water is just as efficient

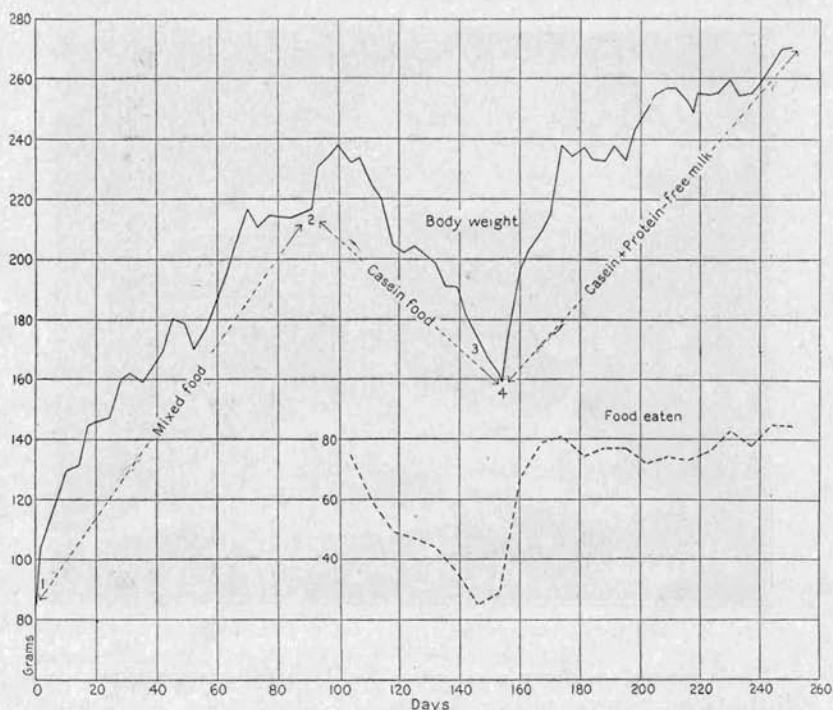


CHART VIII.

Chart VIII is a further illustration of the necessity of an abundance of the water-soluble vitamine in the food, if the animal is to live. In Period 1 the animal grew normally on an ordinary mixed diet. In Period 2, on a diet adequate, except for the lack of this vitamine, it declined rapidly and would soon have died if some source of this vitamine such as protein-free milk (milk freed from fat and protein) had not been fed (Period 3). The protein-free milk contains not only the salts and the lactose of the milk but also the water-soluble vitamine. On the casein diet the weekly food intake (shown by the dotted line at the bottom) declined steadily from nearly 80 grams to a little over 20 grams, but rose immediately to about 80 grams when the protein-free milk (water-soluble vitamine) was given.

as a source of vitamine as is an equivalent quantity of fresh, unheated milk. Even boiling for several hours does not destroy this vitamine.

By what means this vitamine exerts its marvellously beneficial influence is still unknown. The rapid gains in weight following its use are always accompanied by a very great increase in the

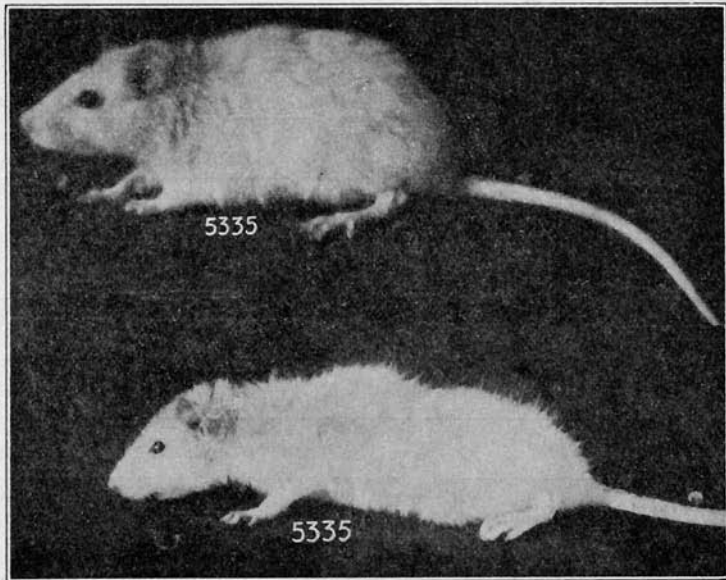


FIGURE 6.

The lower picture shows a rat which had been fed for one month on a diet deficient in water-soluble vitamine. At this time the animal was so weak it was scarcely able to stand and would have died in a few hours if some source of this vitamine had not been furnished. After the picture was taken a small daily dose of yeast which is very rich in the water-soluble vitamine was given to the rat, the food remaining otherwise exactly as before. Twelve days later the upper picture was taken. The result is apparent.

amount of food eaten, the weekly food intake frequently being doubled and sometimes even quadrupled when a small amount of vitamine-containing food is given to an animal declining on a food free from water-soluble vitamine. The vitamine may act simply as a stimulant to a jaded appetite, and the better growth may be

due solely to the increased food intake; or it may supply one or more essential factors needed to complete an inadequate diet, and the effect of adding the vitamine may be analogous to that obtained by adding a missing amino-acid, or a sufficient supply of some inorganic element which was present in too small an amount to permit of normal nutrition. When we know more about the chemical nature of the vitamines, we may be able to discover just what part they take in the processes of nutrition.

Professor Hopkins of England reported some experiments in which he obtained very striking results by feeding daily small quantities of fresh milk to rats which were on a diet supposedly free from water-soluble vitamine. From his data the conclusion was drawn that milk is very rich in this type of food accessory. In some recent attempts to duplicate his results, we found it necessary to use much larger quantities of milk than he did in order to get comparable results.

Undiluted milk contains all the vitamine necessary for the young animal, but in feeding babies it is the practice to dilute cow's milk with water and to reinforce the mixture with milk sugar. By this procedure the vitamine content of the original milk is so far reduced that the bottle-fed baby may get enough of this essential food factor only when it takes a liberal quantity of the food. Whenever appetite fails, the food intake and consequently the vitamine intake are reduced. The effect of this is to further reduce the appetite because the amount of food eaten depends on the vitamine content of the diet. It is thus evident that under such circumstances the child goes from bad to worse and the endless troubles so familiar to mothers ensue.*

In feeding young animals trouble is rarely encountered when

* In this connection it is interesting that Dr. Amy L. Daniels and Dr. Albert H. Byfield have just published in the American Journal of Diseases of Children a report of their experience with additions of the water-soluble vitamine to the milk diets of bottle-fed babes. These experiments were founded on our discovery that milk contains less water-soluble vitamine than had been previously supposed. In each case there was a marked increase in the rate of growth of the infant when the additional vitamine was given and a slowing of the rate when it was omitted. From these experiments it appears that the standard milk mixtures, used for feeding infants, furnish too little of the water-soluble vitamine even when consumed in normal amounts.

the food is right. On the other hand very slight defects in the food lead to countless difficulties.

THE SUGAR OF MILK.

At present we do not know whether or not milk sugar has any greater value for nutrition than have other carbohydrates. It has been thought that liberal quantities of milk sugar in the diet produce lactic acid in the intestine and thus transform the bacterial flora from a type which produces putrefaction to one which checks this process. None of the other kinds of carbohydrates tested has this effect, but to what extent this change is advantageous to the body is as yet undecided.

THE MINERAL MATTERS OF MILK.

Milk also holds a valuable place in the average dietary, on account of the composition of its mineral constituents. Cereal foods contain relatively little calcium, sodium or chlorine, hence animals are unable to grow on diets composed solely of cereals unless these inorganic deficiencies are supplemented. Milk, on the other hand, is rich in calcium, for it contains about three times as much as does the entire wheat grain, and about six times as much as does corn meal. The presence of an abundant supply of calcium in the food is essential, for it not only contributes to the maintenance of the proper neutrality of the body fluids, but is needed to form strong and well-developed skeletons. A liberal consumption of milk by growing children is, therefore, desirable as a "factor of safety" against deficiencies in the mineral nutrients of the other constituents of the dietary.

THE COST AND ECONOMY OF MILK.

Now let us consider the cost of this exceptionally valuable food as compared with other common foods and see how much truth there is in the statement that its cost makes its free use prohibitive to all but a few.

It is difficult to put an exact value on a complicated product like milk, but a fair estimate of its relative value compared with other food products can be reached by calculating the cost of the several types of food elements in milk and other staple products. Milk sugar has the same food value as cane sugar. We can

buy a pound of the latter for 11 cents, so we may assign this value to the sugar in milk. Milk fat has a higher value than have ordinary food fats as shown by the higher price of butter, but let us assume that in milk, fat is worth no more than lard, say about 35 cents a pound.

One hundred pounds of average milk contain about 12.5 pounds of solids of which five pounds is sugar, worth 55 cents at 11 cents a pound, and four pounds of fat worth \$1.40 at 35 cents a pound, or \$1.95 for the fat and sugar. One hundred pounds of milk contain $46\frac{1}{2}$ quarts, which at 16 cents a quart is \$7.45. Subtracting \$1.95 from \$7.45 leaves \$5.50 for the 3.3 pounds of dry protein in the one hundred pounds of milk, or \$1.67 per pound.

Now, how much does dry protein cost in meat or eggs? One hundred pounds of lean round of beef contain 7.3 pounds of fat worth \$2.55. Subtracting this from \$50, which one hundred pounds of this cut of beef now costs at retail, leaves \$47.45 for 19.5 pounds of dry protein, or \$2.43 a pound; 76 cents a pound more than milk protein. The difference is even greater for eggs, for by the same method of calculating, in storage eggs at 55 cents a dozen protein costs \$2.64 a pound, or 97 cents a pound more than milk protein. According to this method of calculation only when the lean round of beef sells for 35 cents a pound and eggs sell for 35 cents a dozen are they as cheap sources of protein as is milk at 16 cents a quart. Thirty-five cents spent for milk at the present price buys nearly as much protein, about two and one-half times as much fat and more than twice as much energy as is contained in a pound of lean Hamburg steak. In buying milk, moreover, one is procuring protein of exceptional value because it enhances the nutritive value of our cereal foods. In addition one is obtaining a liberal supply of vitamins, whose value cannot be estimated in dollars and cents, for as yet we have no adequate knowledge regarding their relative abundance in different foods.

Since milk is so vitally essential as a food for growing children and is such a valuable supplement to a diet composed largely of cereals, vegetables, meat, sugar and fats, the production of milk should be stimulated so that there may be an abundance of milk and milk products of the highest possible grade at prices which shall put them within the reach of all.

SUMMARY.

Milk is absolutely essential for the life of infants and very young children.

It is a most desirable adjunct to the diet of older, rapidly growing children.

It is the main dietary reliance in cases of disordered digestion or extreme illness.

Milk contains an abundance of protein, fat, carbohydrate and mineral nutrients, and its proteins are not only of superior value when used alone, but they are especially adapted to supplement the protein deficiencies of the cereals which form so large a part of the daily ration of mankind. Its mineral nutrients also supplement the deficiencies of the cereals, meat, sugar and fats in these important elements. Moreover it contains the three vitamins without which life cannot be maintained.

The scurvy-preventing vitamin is destroyed by heat and therefore if infants are fed on pasteurized or sterilized milk the use of orange juice or some vegetable extract is necessary to avoid the possibility of scurvy.

Whole milk contains enough water-soluble vitamin to meet an infant's requirements, but if "the top of the bottle" diluted with water is fed, the supply of this essential vitamin may be insufficient unless it is supplemented from some other source.

Milk is the only food known which is capable of serving as the sole constituent of an adequate ration.

Milk is a cheaper form of food at 16 cents a quart than either beef at 35 cents a pound or eggs at 35 cents a dozen.