THE NEWER KNOWLEDGE OF NUTRITION
THE USE OF FOOD FOR THE PRESERVATION OF VITALITY AND HEALTH

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Preface

The need for knowledge of nutrition was never greater than at the present time when so large a part of the energies of the people of Europe and America are absorbed in the activities of war.

The demoralization of agriculture over wide areas, together with the shortage of tonnage for the transportation of food, have reduced the food supply of a number of nations to the danger point, and have cut off in great measure the opportunity for securing the variety which exists in normal times.

The investigations of the last few years have, fortunately, led to great advancement in our knowledge of what constitutes an adequate diet. Such knowledge can, if rightly applied, greatly assist in enabling us to make use of our food supply in a manner which will avoid mistakes sufficiently serious to become reflected in a lowering of our standard of public health. It seems certain that pellagra is the sequel to the adherence to a faulty diet for such a period as to materially reduce the powers of resistance of the body to infection, and reasons are presented in support of the view that there is a much closer relationship between the character of the diet and the incidence of tuberculosis than has hitherto been believed. This view is offered in the present discussion as an invitation to criticism, in the hope that new data either in support or refutation of its validity will be presented. If it shall be definitely proven that faulty diet is the chief factor in the etiology of this disease, and that pellagra, is, as the Thompson-McFadden Commission, Jobling and Peterson and others believe, caused by infection, it will establish that, as the author suggests, large groups of people are at the present time making serious errors in the selection of foods. Regardless of the outcome of future studies relating to the importance of diet to the etiology of these diseases, a non-technical presentation of the kinds of combinations of our natural foods which induce good or faulty nutrition in animals, should be of service in showing the inadequacy of the practice, which is still in vogue, of regarding calories as the factor of prime importance in the planning of the diet.

From the data discussed in the following pages it will be evident that the idea that freedom of choice, and variety of food sources for the diet will prevent any faults in the diet from becoming serious, is no longer tenable, especially if one is willing to admit the existence of many degrees of gradation of mal-nutrition, not recognizable except in their effects on the individual over a long period of time. The author recently enjoyed with a friend, a dinner which consisted of steak, bread made without milk, butter, potatoes, peas, gravy, a flavored gelatin dessert and coffee. The meal was appetizing and satisfying, but such a diet of seeds, tubers and meat would not promote health in an experimental animal over a very long period.

The literature which has a bearing on the application of modem research to the practical problems of human nutrition has become somewhat extensive and is scattered in technical journals, and is not readily accessible, or easy to read in proper sequence. During the present year the author had the pleasure of presenting an interpretation of this literature in the Thomas Clarence Cutter Lectures at the Harvard Medical School. Believing that the publication of these lectures would serve to answer many of the questions which have been asked in numerous letters from the public, they have been edited and presented in their present form.

It is a pleasure to acknowledge the author's indebtedness to those who have assisted in carrying out the experimental work which made possible the discussion of nutrition offered in this book. Nearly three thousand feeding experiments varying in length from six weeks to four years have been observed. Special appreciation should be accorded to Miss Marguerite Davis who assisted with the early work, in the first two years of which no interpretation of the cause of success or failure of our experimental animals was possible, and to Miss Nina Simmonds and Miss Helen T. Parsons for their keen interest and never-failing loyalty to the work.

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CHAPTER I

THE BIOLOGICAL METHOD FOR THE ANALYSIS OF A FOOD-STUFF

Our knowledge of nutrition has progressed hand in hand with the development of the science of Chemistry. Chemical science gave us the clue to an understanding of the nature of the 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. Chemistry will continue, as time goes on, to aid in extending our knowledge of the finer processes of physiology. Nevertheless, it has been possible for a time to advance very rapidly in the study of nutrition, from the technical as well as from the practical standpoint, by a systematic feeding of simplified diets to animals. The results were interpreted on the observations as to the ability, or failure, of the animals to develop normally, as the diets were modified. Progress has resulted in the past, and will continue in the future to come from the judicious division of labor between the study of food problems by chemical methods, and by animal experimentation. In this brief exposition of the present situation respecting our knowledge of foods and nutrition, it is desirable that the reader should appreciate the viewpoint of the investigator, and should understand the line of reasoning by which the successive steps in the progress of the last few years have been attained. A brief historical account of the steps by which research in this field have been developed will serve this purpose, and at the same time, will illustrate the mental processes of a student engaged in the task of bringing order into a field of scientific inquiry where before there was no clear understanding.

A plant structure or an animal body is an exceedingly complex mixture of chemical substances, many of which are individually as complicated in their structure as the most complex machine. The first step in the direction of reaching an understanding of the chemistry of the living mass, must involve the separation and study of the structural units of which the tissues are composed. This was, indeed, the field of activity of many organic and physiological chemists during the nineteenth century. The fats and the simpler substances into which they can be converted as in soap making; the starches and the simpler sugars, and the manner in which they are related chemically; the proteins, bodies having the properties of egg white, the casein of milk, hair, etc., yet very closely related in their chemical nature, since they can all be resolved into the same digestion products in the animal body, or in the chemical laboratory, have all been carefully studied and with marked success. These and a long list of a thousand or more relatively simple chemical substances have been discovered, and isolated in a state of purity from plant and animal tissues. They have been studied to determine their special properties, composition and the tests by means of which they may be recognized and identified.

Through a century of patient labor by many able men, an understanding of the number and character of simple structural units into which the tissues of animal or plant can be separated became realized. Furthermore, certain of these simple bodies could be recognized as intermediate products on their way toward being built up into the most highly organized units of the living tissues; others were shown to be degradation products resulting from the physiological activity of the living tissues of the plant or animal. Through these studies it became established that the body of an animal or the tissues of a plant consists essentially of: proteins, which are peculiar in that they contain about sixteen percent of the element nitrogen, and are complex in structure; starch-like substances and sugars, into which the starches can be easily converted, and fats and a number of closely related, and, in many respects, similar substances known collectively as lipoids. With these there are always associated in the living tissues more or less water and a number of mineral salts. Numerous special varieties of each of these types of substances became known, and their less obvious characteristics were described. Certain substances were found to be special products, found only at certain times and in certain special localities, and these became regarded in their true light, as of subordinate interest. Examples of such are the alkaloids, quinine, strychnine, etc., the cellulose which serves as skeletal tissue for the plant but is not necessary for the animal, and in the same category belong the waste products of the life processes of the animal body, most of which are not found in plant substances. Living tissues, although always associated with numerous substances, the exact importance of which could not be determined, were found to consist essentially of the proteins, fats, sugars, mineral salts and water. These came to be regarded, even as early as 1840, as the essential and never failing constituents of plant tissues and were regarded as the essential constituents of an adequate diet for an animal.

The processes of the digestion of food have excited the wonderment and have occupied the patient attention of some of the most earnest students of physiology and biochemistry. The chemistry of the fats, and the starches and sugars being simpler, or rather less complex than that of the proteins, came to be earlier understood in their essential features. It was not until toward the close of the nineteenth century that the nature and extent of protein digestion became clearly appreciated. Soon after 1900, research of Fischer revealed the great variation in the composition of proteins from different sources.[1] This discovery introduced into nutrition studies the idea of quality in addition to quantity which had heretofore seemed satisfactory to students of nutrition. Most proteins were found to be resolved into eighteen simple digestion products called amino acids, and it was found that the proportions in which these were present in the protein molecule varied greatly in the proteins from different sources. All or nearly all of these digestion products appear to be indispensable constituents of an adequate diet. All natural foods contain several proteins as the extensive and valuable studies of Osborne have shown,[2] and although there are individual proteins which are entirely lacking in one or more of the essential digestion products of proteins, every natural food appears to contain more or less of each of them. The proteins of any single foodstuff may be regarded as biologically complete, but their biological values differ greatly, depending upon the yield of the several, amino acids which can be obtained from them.

Food Analysis.—Since proteins, carbohydrates, such as starches and sugars, fats and mineral salts came to be regarded as the essential constituents of the normal diet, it early became the principal activity of the investigator of nutrition problems do analyze foods of every sort by chemical methods in order to determine their content of what were supposed to be the only essential food complexes. Pronounced differences were observed in the composition of the many substances which serve as food for man and animals. Meats, milk, eggs, and a few seeds such as the pea and bean are very rich in protein, the cereal grains contain less of this food substance, whereas the tubers and vegetables, especially in the fresh condition, contain but very little. Equally great variations are observable in the water content of foods, and in their yields of fats and carbohydrates. One of the great epochs in the development of the science of nutrition, is that in which Atwater and his associates examined and tabulated in classified form the chemical composition of an extensive list of human foods[3]. Following this, similar data were accumulated in the Agricultural Experiment Stations, concerning substances used for animal foods. Up to about 1900, the idea that there was any variation in the quality of the proteins from different sources did not become generally appreciated.

In the light of the revelations in the field of nutrition during the last few years, it seems remarkable that close students of animal nutrition accepted for so long, without proof, the belief that the results of a chemical analysis revealed the dietary values of food-stuffs.

Disease and Diet.—Restricted diets of monotonous character have produced, for centuries, diseases in man in several parts of the world. The only one of these which was at all general in the Western hemisphere was *scurvy*, a disease which caused much suffering among sailors in the days of the long sailing voyages. It was well understood that the disease was the sequel to the consumption of a faulty diet, composed usually of biscuit and salt meats, and that prompt recovery resulted from the consumption of liberal amounts of fresh vegetables and fruits. Decades passed without any systematic attempt to determine the cause of the peculiar value of this class of foods.

Pellagra was a scourge among the poorest of peasants in parts of Europe for centuries, and its etiology has been referred by many to the poor quality of the simple and monotonous diet. This disease was not observed in America until after 1900. Since then, it has been steadily increasing in the Southern States.

Beriberi is a disease common among the poorest classes of the Orient, who limit their food supply principally to polished rice and fish. It is remarkable that not until the year 1897 was the first fertile suggestion made by Eijkman[4], as to the nature of the dietary fault which was responsible for the development of this disease.

Man has been sufficiently industrious in most parts of the world to secure for himself a varied diet, derived from the cereal grains and legumes, fruits, roots and tubers, meats and certain leaves, which he found edible. Beginning with the dawn of the era of his most rapid advance toward achievement, he has in many parts of the world been the possessor and protector of flocks and herds, which provided him with clothing, and a constant supply of both meat and milk. The importance of this last item in his food supply we have just now come to really appreciate. It is in order that it may be fully appreciated how great are the differences in the nutritive value of foods of such a composition as to appear alike from the results of chemical analysis that the present account of the investigations of recent years was prepared.

In the year of 1907 the author began the study of nutrition problems at the Wisconsin Experiment Station {An inspection of the literature which related to nutrition at that time disclosed the fact that the diet was supposed to consist essentially of protein, carbohydrates and fats, and a suitable amount of several mineral salts.} There were in the literature two papers which were highly suggestive that a new era was about to dawn in this field of research. Henriques and Hansen,[5] believing that gliadin, one of the proteins of wheat, was free from the amino-acid lysine, had made up a diet of purified gliadin, carbohydrate, fats and mineral salts, and had attempted to nourish on this food mixture, animals whose growth was complete. It was reported that rats had been kept in a state of nitrogen equilibrium, and even retention of nitrogen (protein) was reported during an experimental period covering nearly a month. In most of their trials the animals failed steadily from the time they were confined to food of this character.

Willcock and Hopkins[6] had conducted experiments with similar food mixtures, composed of carefully purified food-stuffs in which all the constituents were known. When the protein of the diet consisted solely of zein, from maize, the mice lived but a few days. When to this food the amino-acid tryptophan, which is not obtained on the digestion of zein, was added to the diet, the animals lived distinctly longer than without this addition. All experimental work with such diets indicated that they were unable to support well-being in a young animal during growth over a prolonged period. It was an interest in these results, and a desire to know why such food mixtures, which complied with all the requirements of the chemist and the dietitian, failed to properly nourish an animal that led to the decision that the study of nutrition offered a promising field of activity.

At the Wisconsin Experiment Station there was in progress at that time an experiment which greatly strengthened the author’s conviction that the most profitable point of attack for the study of the problems of nutrition, lay in the study of greatly simplified diets so made up that every component should be known. It seemed that, employing such diets, and by the systematic addition of one or more purified substances known to be found in natural foods, or in animal tissues, it should be possible to arrive at the solution of the problem of just what chemical complexes are necessary in the diet of the higher animals.

The above experiment was based upon earlier work by Professor S. M. Babcock, and was suggested by him, and carried out at first by Professors Hart and Humphrey, and later with the cooperation of Mr. Steenbock and the author.[7] In this experiment the object was to determine whether rations, so made up as to be alike, in so far as could be determined by chemical analysis, but derived each from a single plant, would prove to be of the same value for growth and the maintenance of vigor in cattle.

The ration employed for

A. one group of animals was derived solely from the wheat plant, and consisted of wheat, wheat gluten and wheat straw; for a
B. second group the ration consisted entirely of corn plant products, and included the com kernel, corn gluten, a by-product of the .corn starch industry, and the leaves and stalks of the com plant (corn stover);
C. the third group derived their ration solely from the oat plant, being fed entirely upon rolled oats and oat straw. There was
D. a fourth group which it was supposed would serve as controls, which was fed a ration having the same chemical composition, but derived from about equal parts of wheat, corn and oat products.

The animals employed were young heifer calves weighing about 350 pounds, and were as nearly comparable in size and vigor as could be secured.

They were restricted absolutely to the experimental diets, and were well cared for. They were given all the salt ($NaCl$) they cared to eat, and were allowed to exercise in an open lot free from vegetation. Their behavior during growth and in performing the functions of reproduction, were extremely interesting.

All groups ate practically the same amount of food, and digestion tests showed that there was no difference in the digestibility of the three rations.

It was not until the animals had been confined to their experimental rations for a year or more that distinct differentiation in their appearance was easily observable.

A. The corn fed group was sleek and fine and were evidently in an excellent state of nutrition.
B. In marked contrast stood the wheat fed group. These animals were rough coated and gaunt in appearance and small of girth as compared with those fed the corn plant ration. The weights of the two groups did not differ in a significant degree.
C. The groups fed the oat plant ration and the mixture of the three plants, leaf and seed, stood intermediate between the two lots just described.
D. The assumption that the animals receiving the mixture of products would do better than any of the others, and thus serve as the standard group for controls was not realized. The corn fed animals were at all times in a better state of nutrition than were those receiving the greater variety of food materials.

The reproduction records of these animals are of special interest.

A. The corn fed heifers invariably carried their young the full term, and the young showed remarkable vigor. All were normal in size and were able to stand and suck within an hour after birth as is the rule with vigorous calves. All lived and developed in a normal manner.
B. The young of the wheat (tarwe) fed mothers were the reverse in all respects. All were born three to four weeks too soon, and all were small and weighed on an average forty-six pounds, whereas the young of the corn fed animals weighed 73 to 75 pounds each. This weight is normal for new-born calves. The young were either dead when born or died within a few hours.
C. The young of the mothers which had been grown on the oat plant were almost as large as those from the corn fed mothers, the average weight being 71 pounds. All of them produced their calves about two weeks too soon. One of the four was born dead, two were very weak and died

within a day or two after birth, the fourth was weak, but with care it was kept alive.

D. The young of the cows fed the mixture of the three plants were weak in most cases, and one was born dead and one lived but six days.

The mothers were kept on their experimental rations, and the following year they repeated in all essential details the reproduction records observed in the first gestation period.

Records were kept of the milk production during the first thirty days of the first lactation period.

A. The average production per day by each individual in the corn-fed lot was 24.03 pounds;
B. for the wheat fed animals 8.04 pounds, and for
C. the oat-fed animals 19.38 pounds.
D. Those fed the mixture of the three plants produced 19.82 pounds of milk per cow per day during the first thirty days.

In the second lactation period the figures for milk production were 28.0; 16.1; 30.1; 21.3 pounds, respectively, per day during the first thirty days.

Through autopsy and analysis of tissues of the young, and analysis of the feces and urines of the animals in the several groups, an elaborate attempt was made to solve the problem of the cause of the marked differentiation of the animals fed these restricted diets. Interesting data were secured which showed marked differences in the character of the fat in the milk of cows from the different lots, and the observation was made that *the urines of the wheat fed animals were invariably distinctly acid in reaction, whereas those from the other lots were alkaline or neutral to litmus indicator*. It was not possible by any means known to physiological chemistry, to obtain a clue to the cause of the pronounced differences in the physiological well-being of the different lots of cows. This experiment confirmed the author's conviction that the only way in *which the problems of nutrition could ever be solved, would be to solve the problem of the successful feeding of the most simplified diets possible*. If this were accomplished it would be possible to proceed from the simple to the complex diets employed in practical nutrition, ascertaining the nature of the dietary faults in each of the natural foods, singly, the seed alone, and the leaf alone before attempting to interpret the cause of malnutrition in animals fed the more complex mixtures.

Such an undertaking as that just described, viz., the solution of the problem of why animals do not thrive on a diet of purified protein, starch, sugars, fats and inorganic salts which contained all the elements known to be left, as ash, on the incineration of an animal body, necessitated the employment of small laboratory animals. This was true for several reasons: First, because it is difficult and laborious to prepare isolated and purified food substances in sufficient amounts for the conduct of feeding experiments; second, it is both necessary and desirable to shorten the length of the experiments as much as possible, consistent with obtaining data regarding growth and reproduction, in order that data may accumulate sufficiently fast to make progress reasonably rapid. The domestic rat seemed to be the most suitable animal, and accordingly it was selected. The rat has a gestation period of but 21 days, and the young are ready to wean at the age of 25 days. The female usually produces her first litter of young at the age of about 120 days, and will as a rule have five litters by the time she reaches the age of fourteen months, which age marks the end of her fertility. The span of life of a rat which is well nourished is about 36 months. When such an animal is employed, it is possible to accomplish within a relatively short time, the accumulation of data regarding growth and reproduction which it would take years to secure with domestic animals of large size, long period of gestation and long span of life.

A sufficient number of comparable experiments have now been conducted with several species of animals to make it appear certain that the chemical requirements of one species are the same as that of another among all the higher animals. The requirements with respect to the physical properties of the food vary greatly. The ruminants must have bulky food with the right consistency, whereas the omnivora (man, pig, rat, etc.), cannot, because of the nature of their digestive tracts, consume enough of such foods as leaves and coarse vegetables, to meet their energy requirements.

The early efforts to nourish young rats on diets composed of purified proteins, carbohydrates, fats and mineral salts, confirmed the results of the earlier investigators. The animals lived no longer on such food mixtures, than when allowed to fast. The rations employed were of such a character that the most thorough chemical analysis could reveal no reason why they should not adequately nourish an animal. It seemed obvious that there was something lacking from such mixtures which is indispensable for the nutrition of an animal, and a systematic effort was made during the years that followed to discover the cause of failure of animals to develop on diets of purified and isolated food-stuffs. It was not until 1912 that light began to be shed upon the problem.