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THE STUDY OF HUMAN NUTRITION: THE OUTLOOK TO-DAY *

BY

SIR FREDERICK GOWLAND HOPKINS, Sc.D., P.R.S., F.R.C.P.

SIR WILLIAM DUNN PROFESSOR OF BIOCHEMISTRY, UNIVERSITY OF CAMBRIDGE

Among all the demands which the body makes on its environment that for its food is of outstanding importance, and it is to-day becoming well recognized that right nutrition, and especially right nutrition early in life, may profoundly affect the well-being and social value of the individual. Throughout all the earlier and most prolonged stages of his evolution man depended for guidance in the search for food, or later in its production, on instinct, aided by very slowly growing transmitted experience. He depended no less upon instinct and appetite for choice of the right food. What is perhaps remarkable is that the spirit of scientific inquiry had been active for two centuries before even the most civilized communities became provided with guidance of a more definite and reliable kind. The results of the experience obtained by successive generations had become more and more available because recorded, and social organization, of course, brought food to the doors of all who could afford it. But fundamentally the available guidance bearing on quantity and choice was scarcely different in kind from that possessed by primitive man or by primitive communities to-day.

Neglect and Disbelief

For many years after the scientific study of nutrition began in earnest in the middle of the last century its results had little influence on the lay mind. It progressed in an atmosphere of neglect and disbelief. The work of the scientific investigator is always under suspicion with the majority when it professes to throw new light on traditional or customary human activities. Apart from the natural reaction of the average citizen, even that of practical agriculturists, administrators, and a good many physicians, when first presented with scientific data concerning the production and utilization of foods, was to assert that they could be of no more than academic interest. The race, it was felt, had survived through the ages without such knowledge, and science could not improve practice to any significant extent. There are some, I think, who feel the same to-day. But mere survival of a race, however long, is no proof that the majority of its members have ever lived in optimal conditions, or have ever displayed to the full their innate capacities. It is easy to illustrate this from human history, and illustrations are available to-day.

It may be fairly said that not till the end of the eighteenth century did knowledge arise which was fated to be one of the foundation stones of modern nutritional science. I mean, of course, the proof by Lavoisier, by experiments which for that day were remarkably quanti-

tative in kind, that the body burnt its food just as fuel is burnt, and that the oxygen consumed in the process, and therefore the materials oxidized, is directly proportional to the work done by the body. The great Frenchman showed how fully he understood the significance of this by commenting on the irony of the circumstance that those who labour the hardest are usually the least able to afford the food to support their labour. Lavoisier opened an entirely new era with study of nutrition—the era of quantitative experiment, and therefore the scientific era. We can indeed be fair to earlier students only by remembering that not until the fundamental sciences—chemistry, physics, and biology, and especially the first—were sufficiently advanced could our present quantitative conceptions of metabolism possibly originate.

Unfortunately the profound significance of Lavoisier's results became little known or understood for many years afterwards by those responsible for the feeding of communities, a circumstance that I will later illustrate. It was, indeed, many years before further scientific knowledge was built upon the foundation stone of Lavoisier's teaching.

Liebig's Nutritional Studies

The nutritional studies of Liebig began about 1840. Liebig's results, and the doctrine he built upon them, are doubtless familiar to many present, but I always feel it profitable to take Liebig's views, which involved the first theory of nutrition, as a base line from which to measure the extent of modern progress. Liebig was one of the founders of organic chemistry, and no less a pioneer in its application to the plant and animal. He was well aware that the prime necessities in animal nutrition are the three proximate foodstuffs—proteins, fats, and carbohydrates—provided by the synthetic activities of the vegetable kingdom. Nothing was known then of the essential nature of proteins, though they were recognized as being the carriers of nitrogen and essential constituents of all living tissues. Liebig, who had himself developed the methods of organic analysis, found that the percentage composition of proteins from various sources was essentially the same. His view, therefore—differing greatly from our own—was that the proteins of food when eaten are easily, directly, and almost unchanged, built up into the tissues of the consumer.

His doctrine made a sharp and simple distinction between the fate of proteins in the body and that of the other foodstuffs. Their paths, he taught, do not meet. The fats and carbohydrates, he held, have no share in true vital activities. They remain, as it were, dead stores of fuel, to be burnt uncontrolled on the arrival of oxygen from the lungs, being used to supply heat, and heat alone. His mind, moreover, was obsessed by a further consequential idea which for a time led to a grave

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error in contemporary conceptions concerning the functions of foodstuffs. He believed that protein once built into living tissue, unlike fat and carbohydrate, can suffer no change except when that tissue is vitally functioning. He held, for example, that proteins of muscle are locked up in its fibres and break down only when the muscle contracts; yet Liebig believed that it is this associated breakdown of protein which supports the power of contraction. If this seems confusing it should be remembered that our clear present conceptions of energy and energy exchanges were not available for Liebig's thought. The practical conclusion from his theory was that protein, and protein alone among the foodstuffs, is able to support muscular activity. Liebig's authority made this belief long current. He held, further, that though protein as protein is never oxidized to serve directly as a source of heat, the products of its breakdown can subserve that function. This he felt to be a necessary assumption to explain heat production in the bodies of carnivora, so large is the proportion of protein in their food. Liebig was a great experimentalist, but his theory of nutrition was not based upon experiment. Yet we know now that controlled experiment is as essential for the progress of nutritional as of all other branches of science.

The Balance Sheet of the Human Body

Between the days of Liebig and the close of the century much good work was done on nutritional problems, though by relatively few investigators, at first chiefly in Germany, but later also in the United States. By studying what may be called the balance sheet of the human body, and by observing what conditions are necessary to encourage gain or prevent loss, the cruder needs of the body became accurately known. In particular, more and more attention during this period was given to the quantitative needs of the individual for a supply of energy in his food. It had become well recognized that all three of the main foods—proteins, fats, and carbohydrates alike—can supply energy for muscular work, and much was done in the endeavour to decide in what proportions these foodstuffs are best supplied. Finally, towards the end of the century, the experimental study of energy demands assumed extreme accuracy. The human calorimeter of Atwater and Rose was the product of many years' labour, the cost of its production being borne by the United States Government. It reached technical perfection, and by its use Atwater and Benedict were able to measure the calories utilized by individuals upon a great variety of diets, in the resting state or doing measured work for stated periods.

The general public when it hears of apparent differences of opinion among experts concerning the number of calories which should be contained in adequate dietaries cannot be supposed to know how great is the amount of accumulated knowledge concerning this question. The trouble, of course, is to apply it amid the differences displayed by human beings, not only in respect of age, sex, and bodily constitution, but still more in the great variation in the mechanical work which individuals are called upon to perform. In the literature of the subject are the results of scores of statistical studies from many countries concerning the energy value of the food actually eaten by communities of various types. Many of these records go back for half a century; many fresh studies are being published to-day. They deal with every kind of community—industrial and others. I have recently been allowed to see one, as yet unpublished, relating to the food consumption of an enclosed monastery. Any pretence to arrive at a real average value from this mass of data has little scientific justification. Nevertheless, it is sometimes necessary for administrative guidance to estimate so far as is possible the approximate needs of

individual units in a community. Anyone who studies the available data as a whole cannot, I think, fail to believe that they point convincingly to a mean demand for 3,000 calories a day.

But this convenient and commonly accepted figure (so easy to remember) can properly be applied only to mixed communities large enough for the wider variations to cancel out. In such cases the figure is both justifiable and useful. When, however, the attempt is made to estimate the family needs in a particular class—the labouring class, for instance—in which the work of the bread-winner varies so much, I think any estimate should allow a margin for safety. We are obliged for the purpose of such estimates to produce a figure per unit of population, though the needs of a man, a woman, and children of different ages are so different. To get over this difficulty it is customary to treat the needs of the woman and child as being represented by a certain fraction of the man's needs, and then to convert them by the use of factors into "man values." But the estimations so made have no very sound basis, and for this reason again a margin in the estimate should be provided. I have personally no quarrel with the 3,400 calories which were suggested by a committee of the British Medical Association. I think myself there are good reasons why this figure should also apply to the unemployed.

Although a supply of potential energy in his food proportionate to the internal and external work done by the body is a prime need of every individual, the precise nature of the substances in which that energy is supplied is all-important. The material needs of the body are numerous and highly specific in kind. This is the essence of modern teaching. I will ask you, then, to appraise the sources and the value of our present knowledge concerning these specific materials, which we now know to be necessary for adequate nutrition.

The Proteins

At the very end of the last century illuminating facts concerning the nature of proteins first came to hand, but so complex are these substances that knowledge, won by the labours of very many, has continued to grow ever since, and, on new lines, it is growing fast to-day. Protein molecules compared with those of substances more commonly studied by the organic chemist are large and complex. The molecular weights of some of them are of the order of 30,000, those of others reach 60,000. In the tissues of living organisms many distinct proteins have their place. But these heavy protein molecules have one property related to the peculiar and all-important part they play in the phenomena of life. It is a property which has made one aspect of their behaviour relatively easy to study, and our knowledge of it has illuminated our understanding of nutrition. Every protein when under simple treatment in the laboratory, but also, and more important for our understanding of nutritional functions, when submitted to the processes of digestion, breaks down into rather more than a score of relatively simple substances: the isolated building stones, as it were, from which the original complex structure is constructed. These substances all belong to one chemical genus, that of the α amino-acids, but each is a species within that genus, displaying its own individual properties. Identical amino-acids are constituents of every protein, whether of animal or of vegetable origin, but any one protein differs from all others in that the actual grouping of these constituents in its molecules is peculiar to itself. One protein may further differ from any other in that their respective molecules contain the various constituent amino-acids in differing relative proportions, while, again, a few proteins entirely lack certain of the typical constituents. Thus, though the constituent units of all are the same, each of

these important substances is characterized by a special molecular pattern, and the protein patterns of our tissues may differ widely from those we consume in our food. In the intestine, however, the latter are broken down into their constituent units. When they are thence absorbed they reassemble under the influence of subtle directive agencies into new patterns, those proper to the proteins of the living tissues of the consumer. I have ventured upon these considerations because they lead to a conclusion with practical bearings which is prominent in the teaching of to-day. We hear much of the "biological value" of proteins; of "first-class proteins" as necessary for satisfactory diets. I would like to explain for those who may not have grasped it the meaning of this term. You are probably familiar with what is known as "the law of the minimum," as applied by Liebig to the nutrition and the growth of plants and animals. If any one substance quite essential to growth is supplied in amount which, relative to the demand for it, is minimal, that substance becomes a limiting factor for growth rate and for the value of a diet, no matter how much of other essentials many be supplied. This assumes, of course, that the living and growing parts of the organism always maintain a constant composition, and in respect of the tissue proteins of the animal body this is essentially true. The pattern of its tissue proteins is a constant characteristic of each species of animal. It is an aspect of that chemical specificity which underlies morphological specificity.

The food proteins which can be used with the greatest economy in the body are those which contain all the essential amino-acids in such relative proportions as will correspond most nearly with the proportions required by the living tissues of the consumer. These are the proteins of so-called high biological value; they are the "first-class proteins" which nowadays, as I have said, receive mention whenever diets are evaluated. That different proteins have different values in this sense has been abundantly proved by controlled experiments on animals and to a less extent by experiments on human beings. It will be easily understood that it is animal proteins which, in general, have the highest value. It was long accepted that a man doing average work required a daily ration of 100 grams of protein. More recently we have come to believe that this figure is too high. I can testify as a result of experiments in practical classes, involving estimations of the daily excretions of nitrogen, that the average consumption of Cambridge undergraduates (those in training doubtless excepted) is not above some 80 grams. But in this the proportion of first-class protein is probably higher than the average.

Carbohydrates and Fats

In speaking now of the nutritional functions of carbohydrates and fats I will make less demands on your attention. Liebig viewed them indifferently as so much fuel to be burnt, and until the early years of this century it was widely believed that in a dietary any of the fat present could be replaced by carbohydrate of equal fuel value (or vice versa) without affecting the essential adequacy of that dietary. We know now, however, that each class among the foodstuffs has functions peculiar to itself. The changes they undergo in the body do not follow independent paths; the paths cross and the changes are interlocked. Fats cannot be properly utilized in the absence of carbohydrates. Animal experiments, at least, suggest that, even for normal growth, special forms of fat (the highly unsaturated fats) must be present in the food, and an actual deficiency disease has been recognized in animals as resulting from fat starvation. We are fully justified in believing that an ideal dietary should contain fats and carbohydrates in some due proportion.

Dynamic Equilibrium of Tissue Units

Such facts illustrate the complex needs of nutrition and emphasize the circumstance that chemical events in living tissues proceed not independently, but each as part of a whole; each in direct or indirect relations with all others. No one, indeed, who has given thought to the matter can fail to understand that the chemical events of which every living tissue is the seat must themselves be very complex. In the course of growth or repair heterogeneous food materials are converted by controlled processes of reconstruction into the highly specific material of which each tissue is composed; while the intrinsic activities of every tissue are based upon ordered and sustained progress among a great variety of chemical events. Each tissue unit, each living cell, is a system which, though the seat of innumerable such events, retains, nevertheless, an essential individuality. It displays a condition of dynamic equilibrium which, even when disturbed, tends always to return to a normal mean. It follows that each individual chemical reaction within it must progress in close relation, direct or indirect, with all the other reactions. All reactions must be adjusted with due regard to their nature, direction, and velocity, and, being thus organized, they support the living cell as a dynamic but self-consistent unit. In its organization new materials derived from the food ultimately, if not immediately, find their place, and products of change leave the system; but the actual living material retains its essential chemical identity. Among the chemical events of life organization reigns supreme; it is their outstanding character.

The condition of equilibrium within a living unit which results from such high organization is, as would be expected, highly sensitive to certain forms of disturbance from without. As the equilibrium within the cell is shared by chemical molecules of a highly specific kind, each displaying properties due to its own special structure, it is not surprising that the intrusion of molecules foreign to the cell may create grave disturbances. The entry of a few molecules of a powerful poison, for instance, into the cells of this or that tissue may produce irreversible and fatal disturbances of equilibrium. The ability to produce noteworthy effects is, however, by no means possessed by all foreign molecules. There must be always some special structural aspect to make a molecule "biologically active," and this also determines the nature of its activity.

We have long known that there are molecules which, though they must be supplied from without, are not in the above sense foreign to tissue cells, but, on the contrary, are absolutely necessary for their normal activity. In the animal body such molecules are those of substances not made in the tissues generally, but always locally in special organs, from which a supply is distributed to other organs through the circulation. I allude, of course, to the substances contained in so-called internal secretions, which cannot fail to be familiar to you under the name of "hormones." They are now known to be very numerous, exerting many diverse functions. Each one is a quite specific chemical substance with its own indispensable functions in the body, and extremely small amounts are characteristically required for the fulfilment of those functions. The exact chemical nature of several of these hormones is to-day accurately known.

The Vitamins

Some twenty years ago, however, the realization came that the economy of the animal body calls for the activities of substances with functions apparently akin, in many respects at least, to those of the hormones, which the body itself is nevertheless unable to produce, and therefore must receive them in its food. The indispensable functions of these, like those of the hormones,

are adequately fulfilled by extraordinarily small amounts of each one. These food constituents yield, therefore, no appreciable supply of energy, nor do they serve in any ordinary sense as structural materials. Their presence, like that of the hormones, is 'necessary rather for the normal progress of active events. They have dynamic functions. I am alluding, of course, to the vitamins.

It is an interesting, if at present a puzzling, circumstance that evolution should have left the animal dependent upon its environment for certain of these essential substances in the vitamins, while endowing it with the power of producing others for itself—the hormones. It is noteworthy that certain animals can produce in their own organs some particular vitamin for a supply of which others depend upon their food. In the former case, were vitamins otherwise unknown, the one in question would have been thought of as a hormone.

The activity of research upon the nature, distribution, and functions of vitamins has to-day become intense. The number of papers published describing original work in the field has recently reached a total of approximately a thousand in a single year, or nearly three a day! Whole books have been devoted to single individuals among them. This is another instance of the immense attention which is now being given to nutritional studies. I would, indeed, ask you to regard this circumstance as one of the themes of my lecture. The voluminous nature of the literature devoted to vitamins is disconcerting for one who wishes to summarize what is to-day known about them, or to estimate the outlook their study now presents. Here I must deal with them in a very general way. I must refrain from following up that gradual accumulation of evidence which led first of all to the discovery that substances of the kind are necessary, and later to a realization of their multiplicity and to our growing knowledge of their functions. I think I may assume that you are not unfamiliar with the general nature of that evidence. It began with discriminative feeding experiments on animals, and the results of these became soon linked up with evidence from the study of so-called deficiency disease displayed in human communities. In some of the latter the absence of a vitamin from food is the essential aetiological factor, or at least an essential link, in the chain of their causation. The traditional custom of labelling each vitamin with a letter of the alphabet has proved convenient enough, but will probably not long survive now that our knowledge of their actual chemical nature is fast growing.

Vitamin A

Early in the history of these substances it was recognized that a factor first observed in loose association with animal fats is essential for the growth of young animals, and that in its absence animals and human beings alike display unmistakable pathological symptoms. We know to-day that these symptoms arise primarily from degenerative changes in the epithelial cells which line the exposed surfaces of the body; those of the intestinal mucous membrane, for instance, the skin itself, and perhaps those which line the air spaces of the lungs. Among notable effects of any serious deficiency in a supply of vitamin A to the human body is the serious eye trouble now known as xerophthalmia. This is very common in the East, and by no means unknown in Europe. Most cases are cured by administration of the vitamin. It is remarkable that the condition known as night-blindness may follow from a lack of it, because it is necessary for the formation of visual purple in the retina. Its functions in the body, moreover, are of more general importance than these illustrations may suggest.

Recent studies have established the fact that vitamin A is chemically closely related to a group of vegetable

pigments known as the carotenes, and that when these pigments are contained in the food, although they themselves have no specific influence on nutrition, they are converted by the agency of the liver into the vitamin. Apart from its chemical interest, this circumstance has great practical importance, since green vegetables contain carotenes. Indirectly, therefore, they form an economical source of this necessary nutrient.

Vitamin A is among the vitamins which chemical skill has recently isolated in a pure condition, and its actual constitution is now known. Unlike certain others which are crystalline substances, it is, when pure, a yellow oil so potent in its action that 0.005 milligram, about one ten-thousandth of a grain) represents the 'daily needs of a rat, and one five-hundredth of a grain probably suffices for a human being.

In the early days of vitamin research one with functions essential for the maintenance of normality in the nervous system was recognized and labelled B. But preparations of which the observed activity was supposed to be due to this alone have proved to contain other potent vitamins, and we now have to speak of the "B complex." I will return later to a consideration of this.

Vitamin C: Ascorbic Acid

Vitamin C is now familiar as the preventive of scurvy, a disease which is still a scourge in some of the world's communities, while a terror to those who voyaged long without a supply of fresh foodstuffs. This vitamin has now been obtained pure in the form of a white crystalline substance, of which the constitution is known, and the necessary daily supply for a small animal is some 3 milligrams, or one-twentieth of a grain. The vitamin is specially, but not exclusively, concerned with maintaining the normal nutrition of the smaller blood vessels. The haemorrhages which are characteristic of scurvy are due to the degeneration of these.

It is extremely interesting to realize that a substance able to exert such specialized functions should be—as it is—quite closely related to substances which are themselves ordinary foodstuffs; to the simpler carbohydrates; to the sugars. I would have you note, too, as illustrating the close relationship between the molecular architecture of a substance and its power to display this or that special physiology actively, that when the spatial arrangement of the H and OH groups which are attached to the carbon chain is only slightly different, an otherwise identical substance possesses none of the vitamin's activities. Vitamin C will henceforth carry the alternative name of ascorbic acid. Much interesting work has been done upon this vitamin of late, but I must not dwell upon it.

Vitamins D and E

The presence of vitamin D in the body is essential for proper dealings with calcium, and unless it is present in adequate amount in the food of a growing child, or, alternatively, is produced from an inactive precursor in the body by irradiation (surely a most interesting alternative), the condition of rickets becomes established. Its presence, moreover, is one of the factors necessary for normal dentition. The essential molecular structure of this vitamin has been determined. The vitamin belongs to a class of substances known as sterols, and it is interesting, if we take the view I have already adumbrated that vitamins are exogenous hormones, that this structure in a modified form is shared by a prominent member of the latter class.

In vitamin E we have a substance of which the influence seems necessary for normal development and functioning of the organs of generation—in the male for the development of the testis, in the female for the proper functioning of the placenta. It has been called the "anti-sterility"

vitamin, a term which carries implications of too great specificity. Deficiency of vitamin A, for instance, will ultimately lead to a failure in reproductive powers. The special influence of vitamin E, however, has been abundantly proved in animal experiments, and recent reports from clinics have suggested that its administration may prevent the tendency to habitual abortion which is sometimes displayed by women. The chemical nature of vitamin E has not yet been determined.

The Vitamin B Complex

I will now make such brief reference to the B complex as time will allow. There is, to say the truth, no logical but only a historical reason for grouping these vitamins together. That one of the group which is needed for the proper maintenance of nerve tissues is now known as B₁. The recognition alike of its existence and the special sphere of its functions came, not from experimental studies alone, but from the proof that its absence from certain dietaries is the prime, though it would seem not the sole, factor in the causation of beri-beri, a disease in which nerve degenerations are a prominent feature. Much labour has been spent in the endeavour to prepare this vitamin in a pure state, and we now know its empirical chemical formula with some certainty, though its structural formula is not yet determined. Unlike other known vitamins it contains the element sulphur in its molecule.

The use of the pure B₁ vitamin in animal-feeding experiments has shown that though it serves all the functions originally attributed to it in the preparations which in earlier experiments served for its supply, it must have been associated with other vitamins. These preparations were also supplying their unsuspected needs. They contained, for instance, what for a time we knew as vitamin B₂; but the most recent studies have shown that B₂ itself consists of two factors. When one of these is absent from the food growth is not normal, and in the absence of the other an animal develops severe symptoms which resemble those of human pellagra. Very interesting knowledge concerning the former factor has now arrived. Just as vitamin A is related to one group of natural pigments, the carotenes, so is the growth factor of B₂ related to the flavines. These latter are yellow fluorescent pigments, somewhat widely distributed in nature. In very small amount a flavine is present in milk. Brilliant synthetic studies just carried out at Heidelberg have decided the structure of this, and the biological evidence seems to prove that it is the actual growth-promoting factor of the B₂ complex.

Once again we find a condensed ring structure; this time in association with the carbon chain of a sugar. When given to a young rat which has ceased to grow from lack of it normal growth is induced by 0.015 milligram a day, or by about one five-thousandth of a grain. The name B₂ will probably be allotted to this substance, and another will go to the factor which prevents the development of the grave pellagra-like symptoms in experimental animals. To this latter I must spare no more than a reference, though it is of great importance. Though the aetiology of pellagra in human beings has aspects yet obscure, there is no doubt that a diet deficiency plays an important part in it, and remarkable cures by administration of preparations containing this B₂ factor have been reported of late. Pellagra in South America is a widespread and fatal disease, and even in Europe it not infrequently appears as the result of inadequate institutional feeding.

The proof that yet other factors of the vitamin type are necessary for complete nutrition seems imminent, but with these I cannot deal. The complexities in these nutritional needs, brought to light by experimental studies, are disconcerting, but must be faced. I would here emphasize

the enormous advantage to these studies which accrues from the determination of the actual chemical nature of vitamins. This is giving greater objectivity to the facts won, and in the not too distant future it will help us to discover how and why these substances, so powerful in such minute amounts, intrude into and, like the hormones, control, each in its own way, the subtle chemical processes in living tissues.

I have perhaps over-emphasized the association of vitamin deficiencies with actual diseases. It cannot be made too clear that even a relative deficiency in any one of them may be the cause of subnormal health, and if long continued in infancy or youth may do permanent harm.

It is always desirable that the necessary supply of vitamins should be consumed in natural foods, but the increasing availability of reliable commercial concentrates, and especially of the pure substances, is fortunate. The use of these as therapeutic agents has grown rapidly abroad, though less rapidly in this country. Many reports come to hand, recording sometimes, though not always, even startling successes in their employment. Some time must elapse before the merits and limitations of vitamin therapy will become fully known.

Mineral Requirements

Studies of the mineral needs of the body have been proportionately not less active during recent years than those concerned as the organic nutrients; and these needs prove to be no less important and scarcely less various than those for the latter. There is an analogy, too, between the two classes in that among the minerals relatively large amounts of some are required for what we may call structural purposes (though, of course, much less than of the organic structural foodstuffs), while of others, though they are actual needs, very minute amounts only are required; these are concerned with the stimulation of active processes in the tissues. Thus, a deficiency in lime or phosphorus, of which relatively large amounts are required, may in practice prove to be a limiting factor in the adequacy of a diet, especially in the diet of a growing child. A certain minimum of other elements, such as magnesium and iron, is necessary, and it would seem that a supply of manganese and copper, and possibly of other metals, in minute amounts is also an essential; but adequate amounts of these are usually present in the materials of any average mixed dietary. Characteristic of the body's demands for minerals is the circumstance that in certain cases at least the minimal need for some one element bears a definite proportion to the minimal need for some other. Having thus emphasized the importance of the mineral constituents of food, and also the great activity of present studies in this field, I must say no more concerning them.

Controlled Feeding Experiments

It is clear that the nutritional needs of the body when experimentally analysed prove to be unexpectedly complex. Whatever degree of practical guidance such analysis may prove in its totality to possess, it is yielding knowledge that we should surely wish to possess. I would ask you to agree that it could only have been obtained by means of fully controlled experiments. The first suggestion, and the complete proof that a particular substance is requisite for proper nutrition, comes when with that substance being present in the food of one community and absent from that of another the issue is carefully observed. If its presence or absence is made strictly the one and only difference between the diets we shall have the results of a fully controlled experiment. In general, such complete control can only be obtained in animal experiments, and during recent years a great crowd

of workers has been engaged in pursuing them. The greater number have been carried out on that extremely convenient animal, the rat. The breeding of rats for such experiments has become a profitable industry! Their use, believe me, has been abundantly justified. Without them much of our present knowledge would have been very difficult to win. But all-important as animal experiments are, we cannot ultimately rely on them alone, nor can we wholly rely upon mere observation when we come to transfer the results to human beings. In so far as they are possible, we must perform experiments on man.

Admirable experiments, properly controlled in the sense just mentioned, have been successfully made on human subjects. I will instance that carried out for the Medical Research Council by Corry Mann. The effect of adding a daily pint of milk to the accustomed dietary of a boys' home was observed for at least one year. The results were striking enough. The boys who remained upon the basic diet which, judged by ordinary standards, was adequate, gained on the average only 3.85 lb. during the year and showed an average growth of 1.84 inches. Those taking the milk in addition gained little short of 7 lb. each and their average increase of height was 2.63 inches. The betterment in general health was obvious to unprejudiced eyes. Very fully controlled again were Dr. May Mellanby's large-scale experiments on children at Sheffield and Birmingham, proving statistically the benefit of adding vitamin D to the diet as a preventive of dental caries. Scientifically controlled again were the experiments of Dr. Edward Mellanby, showing the influence of vitamin A in decreasing the liability to certain infections.

There is no question that the position of nutritional studies at the moment calls urgently for further experimental research on human material in controlled conditions. This is necessary for putting our present knowledge on the soundest possible basis and for advancing it on desirable lines. The results of such experiments, moreover, are more apt to bring conviction to the majority than those done on animals. They call, however, for much organization, and they need to be prolonged. They therefore need considerable financial support.

I have claimed that animal experiments have proved to be necessary for the first detection of the subtler nutritional needs, and often for the strict proof of suggestions which arise from observation. Owing to the justifiable concentration in such experiments on individual nutritional factors, they are apt to neglect the circumstance that there may be, and commonly is, complexity in the causation of nutritional failures as displayed by mankind.

I will illustrate what I mean by reference to the functions of vitamin A. You have heard that its influence on the integrity of epithelial surfaces has been chiefly emphasized, and rightly so. Vitamin D, on the other hand, has received much attention as contributing to the normal processes of dentition; again rightly so. But evidence has recently arrived to suggest that A also plays a part in dentition; as, in parenthesis, also does C. Doubtless these different vitamins influence different processes involved in the complex growth of a tooth. Again, for the normal maintenance of skin nutrition we have heard much of the importance of the special factor in the B₂ complex, but it would seem that the influence of A is scarcely less important here. Yet again: we have for years attributed beri-beri to the absence of B₁ alone, and to judge from the original evidence on which this assumption was made it can hardly fail to be an important factor in the aetiology of that condition. But Dr. Edward Mellanby has recently called attention to the fact that the nature of the nerve degeneration in beri-beri differs in detail from that shown in B₁-deficient animals, and he brings evidence to suggest that a deficiency in A is also a factor

of importance in the causation of beri-beri. Once more, although vitamin E has such specific relations with the organs of generation, yet loss of fertility also follows prolonged absence of A from the food. It is quite possible that each vitamin possesses, nevertheless, a strict specificity in its action, but the causation of a pathological phenomenon as observed may well be complex.

Labour has been well spent in the analysis of nutritional needs, by demonstrating the nature and multiplicity of the individual factors concerned. These labours must still continue. Yet such is the nature of the body as a whole that we must at the same time endeavour to view nutrition from some unitary standpoint. Every factor in a dietary exercises its functions in union with those of others, and we have yet to learn with more exactness what should be the balance among them in an ideal dietary.

So large is the field I have endeavoured to cover that my survey has inevitably been superficial, but I have at least reminded you of the complexity of nutritional needs as revealed by scientific research during the last two decades. Nearly forty individual substances, it would seem, must be present in a food supply to make it completely adequate.

Practical Applications

But if now we turn to appraise the practical value of this knowledge, complexity after all gives way to relative simplicity. Sir Walter Fletcher once remarked that, whereas in the applications of physical science theory usually had a long start on practice, because many steps involving inventive ingenuity usually intervene, in biological science, and certainly in nutritional science, significant practical applications prove possible, even when theoretical knowledge lags behind. Twenty years ago, for instance, it became easy to correct the then current belief that calories and protein are the sole criteria of adequacy in diet, though we had little knowledge of the actual nature of vitamins or of other specific factors.

It is sure that if enough of natural foods in the right combination are available for the individual he need be in no danger of suffering from any form of malnutrition. Indeed, much of the teaching of modern research may be summed up in statements so simple that our elaborate scientific efforts may to some minds seem to have been superfluous. To convey the essentials of to-day's scientific teaching we have only to insist that fresh green vegetables and fruits are not luxuries but necessities, and that cereal foodstuffs, and especially cereals artificially fractionated, must not so dominate a diet as to exclude an adequate supply of fresh animal products; if not of flesh, then of the products of the dairy. Here we have, one might say, five-sixths of the gospel of right nutrition stated, doubtless, in terms which are too general for complete guidance. Yet a quarter of a century ago official scientific teaching laid no emphasis on the essential points involved, and mistakes in public policy have followed upon ignorance of these. Ordinary experience, even of intelligent men, does not endow them with sufficient knowledge to decide upon such matters. I may illustrate this by two instances, one old and one very recent.

The first was an occurrence in Millbank at the beginning of the last century. The officers of this penitentiary, partly for economic reasons and partly it may be for reasons of discipline, determined to try an experiment in nutrition. The already very inadequate diet of the institution was therefore ruthlessly cut down, though many of the prisoners were engaged in hard labour. The results were complete loss of muscular strength, rampant scurvy, and ultimately the death of thirty persons, rightly followed by indignation on the part of a British jury. This was in the days of complete ignorance as to the nature and quality of individual foods, but Lavoisier had already shown that the body must have fuel proportionate to the work required of it, a fact by no means appreciated by otherwise intelligent officials.

The second instance is of a different kind. A short time ago the island Nauru in the Pacific suffered from a most alarming outbreak of beri-beri, especially of infantile beri-beri. The able medical officer of the island, Dr. Bray, soon arrived, however, at the cause of this. The officials in charge of the island had first of all encouraged the consumption of milled cereals, and then forbade the consumption of the intoxicating national drink—"toddy"—made from fermented sweet swathe of the coco-nut. But removal of the husk from native grains had made toddy the sole source of vitamin B₁ in the food of the inhabitants; hence the disaster. Timely dietary reform soon arrested the outbreak.

Similar instances would not be difficult to quote: war-time provided not a few. It is dangerous for authority to control food policy in ignorance.

I will return for a moment to the use of cereals in diets. It is a familiar circumstance that the economic factor controls the relative amounts in which they are consumed. Bread is by far the cheapest of foods, and with falling spending power it tends always to increase as a constituent of family diets. Cereals, indeed, can never lose their great importance as foods, but to-day we realize that the qualitative deficiencies they undoubtedly present, together, apparently, with certain positive faults, must be corrected by supplying in adequate proportion the more expensive foods which can correct these errors. Economic policy must inevitably be adjusted to meet such facts.

Needs of the Growing Body

You will not expect me in a lecture such as this to discuss the right constitution of practical dietaries. Guidance concerning them is now easily available. It is time, however, that I should refer to the circumstance that the facts under discussion acquire their greatest significance when the well-being of infants, growing children, and adolescents is in question. The growing body has more urgent need for first-class proteins, vitamins, calcium, phosphates, etc., than has the adult body, and suffers when supplied with these over-cerealized dietaries which are deficient in these. Thinking of the special needs of the young raises at once the question of the national milk supply: its production and distribution and its purity. Apart from its necessary and obvious functions in infant feeding, there is abundant evidence, not of the vaguer sort but based upon sound experiment and observation, that milk is an exceptionally valuable food during the whole period of growth. It would seem, indeed, that, apart from merits which would be expected from its known constituents, its high quality proteins, its richness in lime and phosphorus, and its (less abundant) vitamins, milk must possess some subtle qualities—perhaps due to some special association among the constituents—as a food-supporting growth. I do not pretend this is scientifically proved, but there is certainly much evidence to suggest it.

The Value of Milk

The merits of milk were clearly displayed in the Woodford experiment already mentioned. Experiments, not so perfectly controlled but very convincing, have been conducted in Scotland, the United States, New Zealand, and Japan, and lately on a smaller scale in many other centres. The admitted beneficial effect of a milk ration upon Japanese children is very interesting, as so little is normally consumed in that country. Not a few writers, face to face with the malnutrition of certain classes of the population in China and Japan, have attributed it in part at least to the absence of an adequate supply of milk. Our educational authorities have fully recognized the value of giving extra milk to school children. Four years ago the practice was extended, and recently, owing to Government action, still more is reaching the schools.

It is to be hoped, amid the great attention now being given to milk production, milk prices, and milk purity, that inquiries should extend to the question whether the existing methods of its distribution to the general public are the best possible. On the much-discussed question of the merits and possible demerits of pasteurization I will only say this: I have myself had reason to review the voluminous literature which bears upon this matter, and somewhat against my preconceptions I have come to the belief that pasteurization, when properly carried out (an important reservation), affects the nutritional value of milk to no more than a negligible degree. This was recently the conclusion of an expert committee of which I had the honour to be chairman. Nevertheless, I am sure that it is sound policy to encourage the practice of giving orange juice or its equivalent to all milk-fed infants to increase its antiscorbutic power, and further, that during our sunless winter small amounts of cod-liver oil should be given as a source of extra vitamins A and D.

The composition and qualities of milk, representing as they do Nature's own effort to provide a food complete in itself, support the modern claims concerning the complexity of nutritional needs. Of the many factors that recent research has revealed as essential, all or nearly all are contained in it. Its qualities are doubtless specially adjusted to the period of growth, but growth does not cease with infancy. In later periods milk can only constitute a portion of the diet, but it adds something of quite special value. It seems, indeed, that this brief reference to this (nearly) perfect food may logically close my discussion of the factors necessary for complete nutrition.

Knowledge yet to Come

There can be no doubt that a general and intelligent application of existing knowledge would lead to betterment in the health of the nation, and, as I have claimed, the guidance it offers can be simply applied. This, however, is not to say that our knowledge is complete. This is far from being the case. As I have hinted, we do not yet know the optimum intake of calories for children of different ages; our data for determining the needs for first-class protein in various circumstances are vague, and this is a matter of economic importance. Moreover, in the case of human beings, the optimum supply of individual vitamins is still uncertain. We do not know what beneficial modifications of a dietary may be desirable at special periods of life, as at puberty, for instance, or in the case of a pregnant woman. These are merely instances of knowledge yet to come.

Nine public lectures, on "Health and the Law," arranged by the Jewish Health Organization of Great Britain, are to be given, at 8.30 p.m., on Saturday evenings, from March 30th, at the Whitechapel Art Gallery, High Street, Whitechapel, E.1. These and subsequent lectures will deal in a popular way with various aspects of personal hygiene, and will also aim at describing the legal or administrative position of the principal public health services, with a view to a fuller appreciation of their value. The opening lecture, on March 30th, will be a general survey, by Professor W. W. Jameson, of public health in England during the past hundred years. Dr. Maitland Radford will lecture on the control of food supplies; Dr. Hugh Gainsborough, on the essentials of normal nutrition; Dr. J. D. Rolleston, on the prevention of infectious diseases; Mr. H. Lesser, on health insurance and pensions; Dr. L. Mandel, on preventable diseases in infancy and childhood; Dr. C. S. Myers, on the prevention of accidents; and Professor J. F. Browne, on maternal mortality. Particulars of the lecture to be held on April 20th, in association with the People's League of Health, will be announced later. The lectures are open to all free of charge.