'Malnutrition is responsible for widespread impairment of human efficiency and for an enormous amount of ill health and disease, reduces the resistance of the body to tuberculosis, and enhances the general incidence and severity of familiar diseases; mortality rates in infants, children and mothers are higher in ill-fed than in well-fed populations; food consumption at a level merely sufficient to prevent malnutrition is not enough to promote health and well-being.'

'A sound food and nutrition policy must be adopted by each Government if national diets are to be progressively improved, specific deficiency diseases eliminated, and good health achieved.'

'Given the will, we have the power to build in every nation a people more fit, more vigorous, more competent; a people with longer, more productive lives, and with more physical and mental stamina than the world has ever known. Such prospects, remote though they may be, should serve as a stimulus in undertaking immediate tasks and overcoming immediate obstacles.'

Report of the United Nations Conference on Food and Agriculture, Hot Springs, Virginia, United States of America, 18th May-3rd June 1943.

NUTRITION AND NATIONAL HEALTH

being

THE CANTOR LECTURES
delivered before
The Royal Society of Arts
1936

by
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PUBLISHERS' FOREWORD

The three lectures which form the subject matter of this book were the Cantor Lectures of 1936 delivered before the Royal Society of Arts by Sir Robert McCarrison, formerly Director of Research on Nutrition in India. The publication of the lectures in 1936, considered in retrospect, was an event of outstanding importance, as witnessed by the constant reference to them by subsequent writers upon Nutrition and kindred subjects.

It came to the notice of the present publishers that the pamphlet in which the lectures were first published had been out of print for some years. It seemed regrettable that it should no longer be available, in view of the light which the lectures threw on the relation of food and nutrition to public health and of the preoccupation of government and people with this subject at the present time. With this in mind the publishers sought the consent of the Council of the Royal Society of Arts and of the author to reprint the lectures; this was willingly given.

The thesis, sustained in these lectures, that 'the greatest single factor in the acquisition and maintenance of good health is perfectly constituted food', is now an established truth. Various publications of the League of Nations have borne witness to it; and the United Nations Conference on Food and Agriculture, held at Hot Springs, Virginia, in 1943, has set its seal upon it. This Conference declared 'that the first essential of a decent standard of living is the provision to all men of those primary necessities which are required to promote freedom from disease, and for the attainment of good health'; and, 'that the most fundamental of these necessities is adequate food. . . . ' These lectures provide experimental proof of 'the fundamental importance of food in relation to health'. It is hoped that their re-publication will help to extend the knowledge of this vitally important fact among a wider public, to promote the progressive improvement of national diets and, consequently, of national health.

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I

FOOD, NUTRITION, AND HEALTH

When I accepted the invitation of the Royal Society of Arts to deliver the Cantor

Lectures--an invitation by which I was greatly honoured--it was my intention to speak on the more general aspects of nutrition in relation to public health. But during the time that has elapsed since then I have seen, heard and read much both in the lay Press and elsewhere which leads me to believe that the significance of the term, 'nutrition', is not always fully understood. It has seemed to me desirable, therefore, to attempt an explanation of it, for if its meaning be clearly comprehended, its importance to the national health will become self-evident. This explanation must of necessity deal with fundamentals, familiar possibly to many of you. But there may be others of my audience, or who may read these lectures in their published form, whose understanding of nutrition is less complete: to these I especially address myself.

It is not possible to comprehend the relationship of food to nutrition, and of both to health and disease without some understanding of the structure of the body, of the functions of food, of the processes involved in the function of nutrition, and of the pathological changes brought about in the organs and tissues of the body by derangements of nutrition consequent on faulty food.

The Cell

The human body, like the bodies of all plants and animals, excepting those of a very lowly order, is made up of countless millions of cells. Each cell is composed of a microscopic mass of protoplasm enclosed in a delicate membrane and having a differentiated part--the nucleus. Every cell is a perfect physico-chemical laboratory, doing specialized work and needing special materials, both for this work and for the maintenance of its structure and functions The protoplasm, or essential substance of living cells, is the physical basis of organic life. Upon it depend all the vital functions: nutrition, secretion, growth, reproduction, irritability and motility. It is subject to change or differentiation of the most varied sort: forming epithelium, bone, muscle, nerves, glands, organs of special sense, etc. It is a viscid, colloidal material made up of water (hydrogen and oxygen), carbon, nitrogen, and a number of other elements in complex and unstable combinations. The nitrogenous substances, known as proteins, enter largely into its structure, as do a number of inorganic salts. In addition to these, the cells contain another indispensable component: a phosphorized fat called lecithin. This substance facilitates the absorption of nutriment by the cell, the discharge of such specific products as it may contribute to the processes of the body as a whole, and the elimination of the end-products of its chemical activities.

The nucleus is the directing centre of the functional activity of the cell. It consists of a network of filaments whose meshes are filled with a special kind of protein containing phosphorus (nucleo-protein). Along the course of these filaments there are granules formed of an iron-containing protein (chromatin). Upon the integrity of the nucleus and the normal structure of its proteins depend all the vital processes. Presently we shall see how important the specific proteins of the nucleus are, how important are the mineral elements--phosphorus and iron--entering into their composition, how important is the optimum supply to the cells of all elements and complexes needed for cellular activity. For the root of the whole matter of food and nutrition is the nourishment of the cell, whether it be of bone, epithelium, muscle, gland, nerve or special sense. The inevitable consequence of its faulty nourishment is depreciation of its structure and functions--the foundation upon which a vast edifice of disease is built.

Food

Man is made up of what he eats. The constituents of his food are those of which his body is composed. His foodstuffs, derived from the vegetable and the animal kingdoms, consist, for the most part, of matter that is living, that was formerly living or that is derived from matter that was formerly living. Man cannot himself build up living tissue from materials which have in themselves no necessary connection with living protoplasm. This, plants do for him. Out of the earth and air, and under the influence of the sun, they transmute certain inorganic substances--mineral salts, water and carbon dioxide--into organic foodstuffs suited to his use and to the use of the animals whose produce or whose flesh he uses as food. He is, indeed, created out of the earth; and according as the earth provides, by way of plant and animal life, the materials needed by his body, so is that body well, ill or indifferently made and sustained.

Food may be defined as anything which when taken into the alimentary tract provides on digestion materials for the nourishment of the body; materials wherewith its cells fashion themselves each after its kind; materials to sustain their structure and to co-ordinate and control their functions; materials wherewith tissues of specialized functions elaborate their products; and materials to provide energy for cellular work.

The substances wherewith these purposes are effected are oxygen, water and the digestion products of proteins, fats, carbohydrates, inorganic elements and vitamins. Apart from oxygen and water, those at present known to be indispensable to the performance of the body's functions are thirty-six in number. Of these eighteen are amino-acids, derived from the proteins of the food. Eleven are inorganic elements: sodium, potassium, calcium, magnesium, phosphorus, iron, copper, sulphur, manganese, chlorine and iodine. One is glucose, derived chiefly from carbohydrates (though the body can in certain circumstances convert proteins and fats into glucose}. One is linoleic acid, derived from fats. And five are vitamins: called respectively vitamins A, B, C, D and E.

No single foodstuff contains all these essentials. A properly constituted diet is such a combination of foodstuffs as does provide them all in proper quantity and proportion one to another. Their proportion, or balance, is a matter of great importance. We may, indeed, conceive of a properly constituted diet as a system of mutually adapted parts working together; absence or inadequacy of one part deranging the whole system. It may be said of the essential constituents of food, as Marcus Aurelius has said of other things: 'Meditate often upon the connection of these things and upon the mutual relation that they have one unto another. For all are, after a sort, folded and involved one within another and by these means all agree well together.'

In addition to proteins, carbohydrates, fats, mineral salts and vitamins, there are in food blood-forming substances, extractives, flavouring matter and pigments that have parts of greater or lesser importance to play in the nourishment of the body. The food must also contain a certain amount of innocuous, indigestible material, or roughage as it is called, to stimulate intestinal movements. Besides all this, there is something in the freshness of food, especially vegetable food--some form of energy perhaps; it may be certain rays of light or electrical property--which gives to it a health-promoting influence. Certain it is that no synthetic diet that I have been able to devise has equalled in health-sustaining qualities one composed of the fresh foodstuffs as nature provides them.

Further, the quality of vegetable foods depends on the manner of their cultivation: on

conditions of soil, manure, rainfall, irrigation. Thus, we found in India that foodstuffs grown on soil manured with farmyard manure were of higher nutritive quality than those grown on the same soil when manured with chemical manure. Rice grown in standing water--the common practice in India--was less nutritious than when grown on the same soil under conditions of natural rainfall. Spinach grown in a well-tended and manured kitchen-garden was richer in vitamin C than that grown in an ill-tended and inadequately manured one. Examples of this kind might be multiplied, but these suffice to indicate ways in which agricultural practice is linked with the quality of food, with nutrition and with health. If, indeed, man is to derive all the benefits that the soil is so ready to yield to him, he must employ his intelligence and his knowledge in rendering it fit to yield them to him. Impoverishment of the soil leads to a whole train of evils: pasture of poor quality; poor quality of the stock raised upon it; poor quality of the foodstuffs they provide for man; poor quality of the vegetable foods that he cultivates for himself; and, faulty nutrition with resultant disease in both man and beast. Out of the earth are we and the plants and animals that feed us created, and to the earth we must return the things whereof we and they are made if it is to yield again foods of a quality suited to our needs. Man's dependence on the earth is beautifully expressed by Robert Bridges when he says:

From Universal Mind the first-born atoms draw
their function, whose rich chemistry the plants transmute
to make organic life, whereon animals feed
to fashion sight and sense and give service to man,
who sprung from them is conscient in his last degree
of ministry unto God, the Universal Mind,
*whither an effect returneth whence it first began.**

*From The Testament of Beauty, by Robert Bridges Press, Oxford).

Nutrition

Nutrition is the act or process--it is, in fact, the series of co-ordinated processes--whereby the nourishment of the body is effected. It consists in the taking-in and assimilation through chemical changes (metabolism) of materials with which the tissues of the body are built up and their waste repaired, by which the processes of the body are regulated, from which energy is liberated for the work the body has to do, and heat generated for the maintenance of its temperature. Nutrition is thus a fundamental function of the body. By the activity proper to it the structural integrity and functional efficiency of every cell is maintained. This, indeed, is its primary purpose; for if the mechanism of the body be perfect, and continue in perfection, it may be trusted to produce the energy needed for its work provided it be constantly supplied with suitable fuel. It is the mechanism that matters; the fuel (or Calories) is merely a question of the energy the body expends in the maintenance of vital processes--respiration, circulation, secretion, etc.--and in external (muscular) work.

The processes involved in the function of nutrition are mastication, deglutition, digestion, absorption, circulation, assimilation and excretion; the last including perspiration, exhalation, urinary excretion and defaecation There are thus three stages in

nutrition: the first, effected in and by the alimentary tract; the second, in or by the cells composing the body; and, the third by the organs of excretory function--skin, lungs, kidneys and bowel. It is of the utmost importance to realize that not only is the activity proper to the function of nutrition dependent on the efficient performance of all these acts, but their efficient performance is dependent on the adequate nourishment and functional efficiency of the organs and tissues performing them.

At this point, and to maintain the sequence of our story, reference might be made to the implications of these acts: mastication, digestion, absorption, assimilation, and so on. But it may be enough to remind you that they include the ordered operation of involuntary muscular action, the production of various digestive and other juices, the elaboration of ferments, or enzymes, and of catalytic agents needed for the speeding-up of chemical processes, the production of blood-forming substances, the interchange of body fluids, the transport of nutrients to the remotest recesses of the body, the removal of end-products of chemical action and of waste products from the body, and many other vital processes, all of which are influenced favourably or unfavourably by the constitution of the food. The alimentary tract and the organs (including the teeth) associated with it are of particular importance in this connection. They form a highly specialized mechanism designed for the nourishment of the body. The efficiency of the function of nutrition depends primarly on the functional efficiency of this mechanism and this, in its turn, on the constitution of the food.

Let me here draw your attention to some of the tasks which this mechanism has to perform. It splits up, by digestion, the foodstuffs in such a way that the essential nutrients are readily absorbed and made available to the cells in forms best suited to their use. Thus, the many and differing kinds of proteins, present in the plant and animal tissues we use as food, are all decomposed into fragments: the amino-acids to which previous reference has been made. From these fragments, on their absorption, the body builds up the proteins suited to it and to its different parts; for each part its special kind. Mark then, how important it is that the ingested proteins are of kinds that will furnish all the fragments needed. Similarly, the many kinds of carbohydrates--starches, sugars, cellulose--in food are all converted into glucose which is the chief fuel needed for the production of energy, muscular work and the maintenance of the temperature of the body. Likewise, the many kinds of fats, each containing different fatty acids, are converted by digestive processes into soluble soaps which pass readily through the intestinal wall and in their passage are re-converted into the fats needed by the body. The mineral ingredients of food are not only made avallable for use by the body but the intestinal canal itself regulates to a considerable extent their absorption and excretion. Each part of this mechanism has its own contribution to make to the furtherance of the function of nutrition. Thus, the stomach, in normal conditions, not only produces the acid and enzymes needed for gastric digestion but, by its normal contractions, it sustains the appetite for food. It produces, too, a substance which, by its combination with a material or materials of unknown nature contained in certain foodstuffs, gives rise to a product having the specific property of ensuring the normal formation of the red cells of the blood. Absence of one or other of the component parts of this product--that produced in the stomach or that provided in certain foodstuffs--leads to the occurrence of pernicious anaemia. This product is stored in the liver for use as required by the bone-marrow--the birthplace of the red blood cells--hence the use of liver extract for the cure of this disease.

The stomach produces yet another substance which is necessary for the normal nutrition of the central nervous system. Thus early in the process of digestion is the welfare of these two most important tissues--blood and nerve--taken care of, and by the stomach.

Beyond the stomach, in the duodenum, there are glands that not only secrete digestive juices but some that produce protective substances lest the acid contents of the stomach should, after they leave it, erode the mucous membrane of the bowel. The continued production of these alkaline and other protective substances is an important factor in the prevention of duodenal ulcer; and the continued functional efficiency of the glandular cells producing them is dependent on the quality of the food. There is no stage in the whole process of digestion, absorption and passage of the gastro-intestinal contents along their appointed way which is not regulated and controlled by some substance or substances derived from food. Even the time-table of events, which normally proceeds with clockwork regularity, is under such control. It cannot be too insistently stated that disturbance of these processes, disturbance of this time-table, and alterations in form or consistency of the faecal residues are signs that something is going wrong or has gone wrong with the function of nutrition.

The alimentary tract is very prone to suffer both structurally and functionally in consequence of faulty food and to become the prey of pathogenic agents of disease or the harbourer of parasites. Further, states of ill health of this tract often provide conditions precedent to the development of diseases of faulty nutrition. In such circumstances essential constituents of food may not be absorbed in sufficient quantity for the needs of organs and parts of the body, and disease due to their deficiency may arise. Many years ago (1918), when the newer knowledge of nutrition was in its infancy, I obtained some dozens of healthy monkeys from the jungles of Madras. Some I fed on faulty and ill-balanced food deficient in vitamins and mineral elements, others on perfectly constituted food. The latter remained in good health; the former developed gastro-intestinal ailments, ranging from gastritis and ulcer to colitis and dysentery, while one amongst them had a commencing cancer of the stomach. The passage of years has not dimmed the recollection of this crucial experiment nor detracted from the far-reaching importance of the results yielded by it. Indeed, there is, perhaps, no more significant fact in regard to the function of nutrition than that this highly specialized alimentary mechanism on which the nourishment of the body depends is itself amongst the most susceptible of the structures of the body to faulty nutrition.

Nutrition is affected adversely by a number of factors: imperfect oxygenation of the blood and tissues, as from faulty breathing, lack of fresh air, bad ventilation, overcrowding and lack of exercise; insufficient rest and want of sleep; overwork and fatigue; worry and emotional excitement; lack of sunshine; insufficient Calories for the work the body has to do; excessive consumption of alcohol; indigestible food; gastrointestinal disorder; and' many conditions of ill health. But by far the most important factor is food of improper constitution. The determination of the constitution of the food is the first essential in the assessment of the efficiency or lack of efficiency of the function of nutrition; the correction of food-faults is the first essential in the restoration of this function to normal.

Disorder of the function of nutrition, brought about by faulty food, causes the body to react in a variety of ways, depending on the nature of the food-faults that give rise to it, the part or parts of the body effected by it, and the intervention or the non-intervention of

toxic or microbic agents of disease. These reactions, involving as they do disturbance in structure or in functions of various parts of the body, manifest themselves as subnormal states of health or as actual disease in great variety of form.

It will be realized from these considerations how far-reaching are the aspects of nutrition. They include the chemistry of food, the chemical changes (metabolism) whereby the function of nutrition is effected, the activity of the various organs and tissues in response to food conditions, the structural and functional changes induced in organs and tissues by faulty food, and the conditions of the body that result from faulty nutrition. Nutrition touches upon, indeed embraces in its compass, many subdivisions of biology--big-chemistry, big-physics, morphology, physiology, pathology and medicine. Knowledge of it helps to bridge the gulf between physiology and pathology--a gulf in need of bridging--it is, indeed, an essential foundation of rational medicine.

Nutrition is commonly spoken of as a condition of body--excellent, normal or subnormal, as the case may be--when, in truth it is a function of the body on which condition of body--i.e. health--depends. For a proper comprehension of nutrition and of the processes involved in it this distinction has to be borne in mind. Such terms as under-nutrition and malnutrition are nowadays in common use, often without a clear conception of their meaning. Sometimes they are used to signify a condition of body which under-nourished would more fittingly describe; sometimes to signify under-feeding. 'Malnutrition', we are reminded by Fowler in his Modern English Usage, 'is a term to be avoided as often as under-feeding will do the work', for malnutrition is not merely underfeeding but disorder of the processes of nutrition brought about, as a rule, by the habitual use of food of improper quality.

Nutrition is, also, commonly defined as 'food', 'nourishment', 'that which nourishes'. But, as we have just seen, it is something much more than this. Food is the instrument, nutrition is the act of using it. To employ the term 'nutrition' as an alternative one for 'food' is to miss its true meaning, to fall in comprehending not only that in which nutrition consists, but all that is meant by its derangements.

Health

Health is variously defined as 'soundness of body', 'state of bodily or mental well-being', 'freedom from disease, disorder, pain or weakness'. It is, in fact, a variable condition of body as in good, bad, poor or ill health. At its best it is 'that state of being in which all the parts and organs are sound and in proper condition; that condition of the body and its various parts and functions which conduces to efficient and prolonged life. It implies, moreover, the ability to produce and rear offspring fitted to live and efficiently to perform the ordinary functions of their species'.* This optimum state of being can be attained when--but only when--the animal organism is adequately nourished. Further, it is possible to produce at will in animals under experimental conditions every grade of health--good, bad or indifferent--by alterations in the composition of their diets. Specific diseases of many kinds can be produced by feeding them on diets having specific food-faults or prevented by the correction of these faults. The interaction of faulty food, faulty nutrition and microbic or toxic agents leads to the spontaneous appearance of many others or to their controlled appearance at the will of the experimenter. I know of nothing so potent in maintaining good health in laboratory animals as perfectly constituted food; I know of nothing so potent in producing ill health as improperly constituted food. This,

too, is the experience of stockbreeders. Is man an exception to a rule so universally applicable to the higher animals? It seems most unlikely that he can be, although it is to be recognized that his requirements for adequate nutrition, and the effects upon him of deficiencies of various food-essentials, are not necessarily the same as in animals. Indeed, these effects are known to differ in different species of animals. Nevertheless, the principles of nutrition are fundamentally the same in man and in animals. It may, therefore, be taken as a law of life, infringement of which will surely bring its own penalties, that the greatest single factor in the acquisition and maintenance of good health is perfectly constituted food. It is this thesis that I have to sustain in these lectures.

*Century Dictionary.

The Experimental Method in Research on Nutrition

As you are probably aware, it is customary in the investigation of nutritional problems in the laboratory to use the experimental method and to feed animals rats:, as a rule--on synthetic diets composed of purified food-materials, but lacking this or that essential according to the nature of the inquiry in hand. The results of such experiments, though of great value in the ascertainment of the function of a given essential of food, and in the precise determination of the bio-chemical and-pathological changes resulting from its want, are open to the objections that the observations made in rats are not necessarily applicable to human beings, that synthetic diets such as are used in these experiments are never eaten by human beings, that human diets are rarely or never wholly lacking in any single food-essential, that their deficiencies are usually multiple, and, that the diets of mankind are often unbalanced in other regards, such, for instance, as in their high content of carbohydrates relative to other food-essentials. The validity of these objections cannot be gainsaid; nevertheless, it may be remarked in passing that the frequency with which results observed in rats are applicable to man is remarkable--a fact which will be the better appreciated from the examples I am about to place before you. Further, without such experiments on animals the vast amount of knowledge revealed by them within recent years would, for the most part, be hidden from us, and we would still be in ignorance of the kind of consequences to expect in man from his continued use of food of faulty constitution. We would, moreover, be in ignorance of what a properly constituted diet is.

But when in such investigations, diets composed of food-materials in common use by man or diets in actual use by human beings are used in the feeding of our animals, most of these objections do not arise, and the results observed have a more direct application to man, provided the faulty combinations of the food-materials entering into the diets are such as uninstructed man himself commonly employs. It has seemed to me necessary, therefore, to use in my experimental work diets composed of the actual materials that human beings eat; and it is with such diets that most of my work has been done.

Before giving examples of the effects of such faulty diets on the animal organism, let me draw your attention to the relation of the national diets of India to the physical efficiency of the races using them.

Food and Physical Efficiency

Nowhere in the world is the profound effect of food on physical efficiency more strikingly exemplified than in India. As you know, India has some 350 million

inhabitants, made up of many races presenting great diversity in their characteristics, manner of life, customs, religion, food and food- habits. The tribes of the Indian Frontier, and of Himalayan regions, the Peoples of the Plains--Sikhs, Rajputs, Mahrattas, Bengalis, Ooriyas, Madrassis, Kanarese and many others--exhibit, in general, the greatest diversity of physique. And as each race is wedded to its own manner of living, to its own national diet, comparison between them is easy.

The level of physical efficiency of Indian races is, above all else, a matter of food. No other single factor--race, climate, endemic disease, etc.--has so profound an influence on their physique, and on their capacity to sustain arduous labour and prolonged muscular exertion. 'As we pass from the North-West region of the Punjab down the Gangetic Plain to the coast of Bengal, there is a gradual fall in the stature, bodyweight, stamina and efficiency of the people. In accordance with this decline in manly characteristics it is of the utmost significance that there is an accompanying gradual fall in the nutritive value of the dietaries.' So wrote McCay, as a result of his investigations, a quarter of a century ago. My own observations have served to confirm his conclusions, though I find other causes in addition to protein-insufficiency--to which he attached chief importance--for the decline he refers to. This decline extends also to the peoples of the south and west of India, being especially apparent in certain parts of the Madras Presidency. This is not to say that in these parts there are not many people of good physique nor that in the north of India there are not many whose physique is poor. But speaking of the generality of the people, it is true that the physique of northern races of India is strikingly superior to that of the southern, eastern, and western races (Fig. 1). This difference depends almost entirely on the gradually diminishing value of the food, from the north to the east, south and west of India, with respect to the amount and quality of its proteins, the quality of the cereal grains forming the staple article of the diet, the quality and quantity of the fats, the mineral and vitamin contents, and the balance of the food as a whole. In addition to these questions of quality there is the further one of quantity. In regard to the latter little need be said; for it is obvious that if a man is not getting enough to eat he cannot be physically efficient. Unfortunately, the numbers in India who do not get enough to eat may be counted by the hundred thousand.

To see Figure 1 full sized, click here

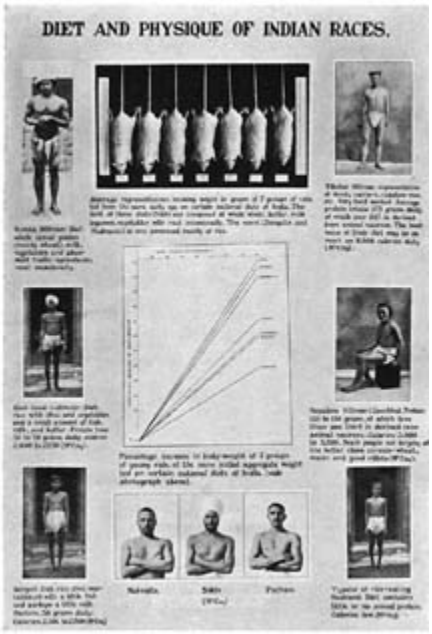


Figure 1. Note fine physique of races (Mahratta, Sikh, Pathan) whose diets are well constituted and poor physique of those (Bengali, Madrassi) whose diets are ill-constituted. Note similar effect on rats fed on those diets. From left to right, the rats represent Sikh, Pathan, Mahratta, Goorkha, Kanarese, Bengali, Madrassi.

In general the races of northern India are wheat-eaters, though they make use also of certain other whole cereal grains. Now the biological value of the proteins of whole wheat is relatively high; and the wheat is eaten whole, after being freshly ground into a coarse flour *(atta)* and made into cakes called *chapattis.* It thus preserves all the nutrients with which Nature has endowed it, particularly its proteins, its vitamins and its mineral salts. The second most important ingredient of their diet is milk, and the products of milk (clarified butter or ghee, curds, buttermilk; the third is *dhal* (pulse); the fourth, vegetables and fruit. Some eat meat sparingly, if at all; others, such as the Pathans, use it in considerable quantity. Their food thus contains--when they can get the food they want, which they do not always do--all elements and complexes needed for normal nutrition (with the possible exception of iodine in some Himalayan regions) and abundance of those things that matter from the point of view of the structural and functional efficiency of the body. In conformity with the constitution of their dietaries they are the finest races of India, so far as physique is concerned, and amongst the finest races of mankind. Familiar as I am with the chapatti-fed races of northern India, I have little patience with those who would have us believe that 'white flour' is as good an article of diet as 'whole wheat flour'. White flour, when used as the staple article of diet, places its users on the same level as the rice-eaters of the south and east of India. They are faced with the same problem; they start to build up their dietaries with a staple of relatively low nutritive value. If their health and physical fitness are not to suffer, they must spend more money

on supplementary articles of diet in order to make good the deficiencies of white flour than if they had begun to build on the surer foundation of whole wheat flour (Fig 2). So it is with rice, which is the staple article of diet of about ninety millions of India's inhabitants. The rice--a relatively poor cereal at best--is subjected to a number of processes before use by the consumer; all of which reduce--some to a dangerous degree--its already sparse supply of certain essential nutrients. It is parboiled, milled or polished; often all three. It is washed in many changes of water and, finally, it is boiled. It is thus deprived of much of its proteins and mineral salts and of almost all its vitamins. Add to this that the average Bengali or Madrassi uses relatively little milk or milk-products, that by religion he is often a non-meat-eater, that his consumption of protein, whether of vegetable or of animal origin, is, in general, very low, that fresh vegetable and fruit enter into his dietary but sparingly, and we have not far to seek for the poor' physique that, in general, characterizes him. In short, it may be said that according as the quality of the diet diminishes with respect to proteins, fats, minerals and vitamins, so do physical efficiency and health; a rule which applies with equal force to the European as to the Indian.

To see Figure 2 full sized, click here.

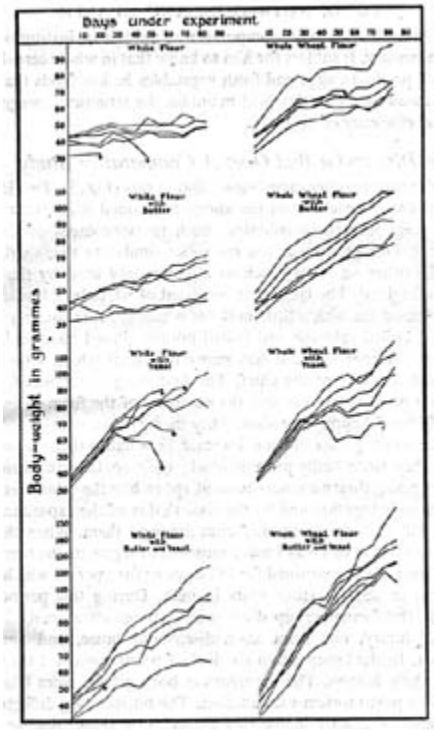


Figure 2. White flour versus while wheat flour, showing individual weight curves of young rats fed on white flour or whole wheat flour alone or in combination with butter or yeast or both.

The arrows indicate day of death (usually from pneumonia). Note high mortality in rats fed on white flour diets: 30 per cent as compared with 4 per cent in those fed on whole wheat flour diets.

Note (1). Whole wheat flour is more suitably constituted to sustain well-being for short periods than white flour when the sole article of food.

Note (2). The addition of butter to a white flour diet improves it but slightly; whole wheat flour and butter is a better diet than white flour and butter.

Note (3). The addition of 5 per cent yeast to a diet of white flour improves the rate of growth but the animals are very prone to pneumonia due to want of Vitamin A.

Relative Values of National Diets of India

This truth will probably be best appreciated by a reference to an experiment carried out in my laboratory some years ago, with the object of determining the relative values of certain national diets of India: Albino rats were employed in this test. The cycle of development in the rat takes place about thirty times as quickly as in man, so that the experiment about to be described, which lasted 140 days, would correspond to the observation of human beings, under the same experimental conditions, for a period of nearly twelve years. Seven groups of twenty young rats, of the same age, sex-distribution and bodyweight, were confined in large, roomy cages under precisely similar conditions of life. To one group the diet as prepared and cooked by the Sikhs, was given; to another that of the Pathans; to a third that of the Mahrattas; and so on through Goorkhas, Bengalis, and Kanarese to Madrassis. The results on the eightieth day of the experiment are shown in Fig. 1; from which it will be seen that the various diets ranged themselves in the following descending order of nutritive value: Sikh, Pathan, Maharatta, Goorkha, Kanarese, Bengali and Madrassi. At the end of 140 days the animals in each group were weighed and an average taken of their aggregate weight. The rat which conformed most closely to the average for its particular group was photographed side by side with the average rats from other groups. The photograph shown in Fig. 1 is the result. From it we see that it conforms to the results of observations made in man himself. In brief, the best diet--that of the Sikhs--contains in abundance every element and complex needed for normal nutrition, the worst diet--that of the Madrassi--has many faults: it is excessively rich in carbohydrates, and deficient in suitable protein, mineral salts and vitamins. Presently we shall see that this difference in the nutritive value of these diets is reflected in the diseases from which the people of the north and south of India suffer.

Freedom of Well-Fed Animals from Disease

So impressed was I by the adequacy of the northern Indian's diet that during the later years of my experimental work I used it as the diet of my stock rats. These numbered about 1,000. Their food consisted of *chapittis* lightly smeared with fresh butter, sprouted Bengal *gram* (pulse), *raw, fresh* vegetables (cabbage and carrots) ad libitum, milk, the hard crusts of bread (to keep their teeth in order), a small ration of meat with bone once a week, and water. They were kept in stock for about two years--a period approximately equal to the first fifty years in the life of a human being--the young being taken as required for experimental purposes, and the remainder used for breeding. During the five years prior to my leaving India there was in this stock no case of illness, no death from natural causes, no maternal mortality, no infantile mortality. It is true that the hygienic conditions under which they lived were ideal, that they were comfortably bedded in clean straw, that they enjoyed dally exposures to the sun practically the whole year round, and that the care bestowed upon them was great; but the same care was bestowed during these

years on several thousand deficiently-fed rats, which developed a wide variety of ailments *(vide infra)* while the well-fed animals enjoyed a remarkable freedom from disease. It is clear, therefore, that it was to their food that this freedom was due. If man himself did not provide in his own person the proof that a diet composed of whole cereal grains, or a mixture of cereal grains, milk, milk-products, pulses and vegetables, with meat occasionally, sufficed for optimum physical efficiency, this experience in rats would do so. It is not, therefore, unreasonable to conclude that if by minute attention to three things--cleanliness, comfort and food--it is possible to exclude disease from a colony of cloistered rats, it is possible greatly to reduce its incidence by the same means in human beings and to produce a race whose physique is as nearly perfect as nature intended it to be.

Supposing now we cut out the milk component of this diet or reduce it to a minimum, we find that disease soon begins to make its appearance, especially if at the same time we limit the consumption of fresh vegetable foods. I have repeatedly made these restrictions with the result that respiratory diseases, gastro-intestinal diseases and maladies consequent on degenerative changes in mucous membranes and other structures of the body become frequent. It is apparent, therefore, that the diet of the Sikhs is only health-promoting so long as it is consumed in its entirety. Indeed, we know that those of this race who, for whatever reason, do not consume adequate quantities of milk, milk products and fresh vegetables, do not long retain the fine physique for which the Sikhs are famous. These food-materials are for them and in their own parlance, *takatwar khurak* (foods that give strength); nowadays we speak of them as 'the protective foods', since they make good the deficiencies of muscle meat, refined cereals, etc., which enter so largely into the diets of western peoples.

Before leaving this experience, let me emphasize two things: the first, that all things needful for adequate nourishment of the body and for physical efficiency are present in whole cereal grains, milk, milk-products, legumes, root and leafy vegetables and fruits, with egg or meat occasionally. What is eaten besides these is more a matter of taste than of necessity. And the second: that the diet must be complete in every essential. It is not to be expected that by substituting, for instance, wholemeal bread for white bread, health will benefit greatly unless the substitution completely restores the balance of an ill-balanced diet, nor that by adding bottled vitamins or mineral elements to a faulty diet its faults will be remedied, unless they be confined to vitamins or mineral elements. The correction of food faults lies first in their computation and thereafter in the construction of a diet so balanced and complete as to satisfy all physiological needs. Fortunately, the layman need not concern himself with such computations, though in institutions they may be necessary. It suffices for him to know that in whole cereal grains, milk, milk products, eggs and fresh vegetables he has foods that, when used in adequate quantities, will maintain the structural integrity and functional efficiency of his body.

To see Figure 3 full-sized, click here.

A Good Diet and a Bad One: A Comparative Study

Consider now another experiment, also in rats (Fig. 3). Two identical groups, twenty in each, from the above-mentioned stock were used in it. They were housed in colonies: both in large cages of the same dimensions. One group was fed on a diet similar to that used by the Sikhs; the other on a diet such as is commonly used by the poorer classes in England. The latter diet consisted of white bread, margarine, over-sweetened tea with a little milk (of which the rats consumed large quantities) boiled cabbage and boiled potato, tinned meat and tinned jam of the cheaper sorts. It has many faults, of which vitamin and mineral deficiencies are the chief. The first thing one noticed, as this experiment progressed, was that the members of the former, and well-fed, group lived happily together. They increased in weight and flourished. The other group did not increase in weight; their growth was stunted; they were badly proportioned; their coats were staring and lacking in gloss; they were nervous and apt to bite the attendants; they lived unhappily together and by the sixtieth day of the experiment they began to kill and eat the weaker ones amongst them. When they had disposed of three in this way I was compelled to segregate the remainder. The experiment was continued for 187 days, or for a period which would correspond to about sixteen years in man. During this period three animals in the former group died--one (a pregnant animal) from an abdominal injury, one from an undiscovered cause, and one from pneumonia. In the latter group six died of pneumonia and three were killed by their fellows. The survivors in both groups were killed and subjected to post-mortem examination. The outstanding differences in the incidence of disease in the two groups were these: disease of the lungs was much commoner in the group fed on the poorer class Britisher' s diet; gastro-intestinal disease (gastritis, gastric congestion, outgrowths of epithelium in the stomach, and intestinal stasis) was frequent in this group, while that receiving the Sikh diet was free from it. Indeed, the animals fed

on the poorer class Britisher's diet fared little or no better than those, in another experiment, that were fed on a diet in common use in Madras, and the maladies from which they suffered were much the same. The results of this experiment indicated clearly that a diet, such as is commonly used by the poorer classes in England, gives rise in rats to two chief classes of ailment--pulmonary and gastrointestinal--while a more perfectly constituted diet, such as is commonly used by northern Indian races, affords a considerable measure of protection against both. It is not unreasonable, therefore, to expect that, other things being equal, similar results will arise in man from the use of these diets. We do, in fact, find that these two classes of ailment are amongst the most frequent of the maladies afflicting the poorer class Britisher (Fig. 5) as well as the poorer class Madrassi.

Food and Peptic Ulcer

Another example may be provided by peptic ulcer (gastric and duodenal). This malady is very common in the south of India, rare in the north. It is, in fact, fifty-eight times more common in the latter part of India; it is particularly so in Travancore. In order to determine whether or not it was related in its genesis to diet the following experiment was undertaken. Three groups of young rats, from the healthy stock above referred to, were fed as follows: one on the well-constituted diet as used by the Sikhs, but reinforced with additional milk; one on the carbohydrate-rich, protein-poor, vitamin-poor and mineral-poor diet in common use by the poorer class Madrassi; and the third on the diet--largely made up of tapioca--in common use by the poorer classes in Travancore, amongst whom peptic ulcer is so common. This diet has many faults, of which protein, mineral and vitamin deficiencies are the chief. The experiment was continued for close on 700 days, a period which would correspond to about fifty years in man. Many animals in the last two groups died during its course, from the usual respiratory and gastrointestinal diseases. The results revealed at post-mortem examination of all the animals were, as far as peptic ulcer was concerned, as follows: first group (Sikh diet), nil, second group (Madrassi diet), 11 per cent; third group (Travancore diet), 29 per cent incidence of peptic ulcer.

Here, again, we see that a disease common in certain parts of India (as it is in this country) can be produced in rats by feeding them on the faulty diets in common use by the people of these parts, while other animals, fed on a perfectly constituted diet in common use by human beings, amongst whom peptic ulcer is rare, remain free from it. Surely, if we are to place any reliance on animal experiments of this kind, we must regard faulty and ill-balanced food as a cause of gastric and duodenal ulcer in human beings? How it causes it, whether by direct or indirect action or want of action, or because of want of this or that essential of food or excess of this or that one, is a matter of little consequence--though of much scientific interest. What is of consequence, not only to the people of India, but, I venture to affirm, to the people of this country, is that by the continued use of a perfectly constituted diet they are unlikely to develop gastric or duodenal ulcer.

Experimental Beri-Beri and 'Stone'

Examples of this kind, occurring in my own experience, might be multiplied to an extent that would occupy many hours in their narration. I must, therefore, limit their

numbers. Two will suffice: As no doubt you all know there is a disease called beri-beri, which is prevalent in certain parts of the tropics, chiefly amongst rice-eaters. It is not prevalent amongst rice-eaters in other parts of India, nor is it so prevalent in its endemic homes as a comparatively recent broadcast by the B.B.C. may have led some of you to suppose: every other woman in the south of India does *not* suffer from beri-beri. About forty years ago Eijkman noticed that if fowls were fed on an exclusive diet of polished rice they developed a type of polyneuritis which had certain likenesses to beri-beri--a malady in which polyneuritis is a prominent symptom. He found, moreover, that they did not develop this 'nutritional polyneuritis'--as he rightly called it--when they were fed on unpolished rice or on polished rice to which the rice-polishings were added. So he, and his colleague, Grijus, concluded that there was something--vitamin B_1 as it ultimately proved to be--in the rice-polishings which prevented the nutritional polyneuritis in birds, a something that might possibly prevent beri-beri in man, as indeed it (vitamin B_1) is now known to do. But to prevent is one thing, to cause, if the preventive be removed, is, or may be, another. It is nowadays an almost universal belief that on a diet of polished rice or on a diet devoid of vitamin B_1 beri-beri develops after a few months. Theoretically, this is possible, in practice it is a rare occurrence. For no one, even in localities where beri-beri is endemic, ever does live on an exclusive diet of polished rice or on a diet devoid of vitamin B_1 always the diet contains some of this factor, however little that may be. Further, only a relatively small proportion of persons subsisting on diets deficient in vitamin B_1 do develop beriberi, even in endemic areas of the disease. If one feeds pigeons on a diet almost devoid of this vitamin they develop polyneuritis, but polyneuritis is only one of the symptoms of human beri-beri; there are two others, equally important grave disorder of the heart and oedema. Now supposing one does, as I have often done, feed pigeons on diets similar to those in actual use by human sufferers from beri-beri, then we find that a disease having all the pathological characters of true beri-beri does develop in a proportion of the birds, just as it does in a proportion of human beings. But this diet is not devoid of vitamin B_1, although it is low in it. It does not contain enough of it to prevent the disease, or enough of some other factor in addition to vitamin B_1, to prevent the development of the complete syndrome, or, alternatively, to prevent the development or operation of the ultimate causal agents of the malady. Now if in such a diet one substitutes whole wheat flour for a part of the rice and at the same time we add to it fresh vegetables, such as tomatoes, then the disease does not arise, either in birds or in man. I have, myself, so prevented human beri-beri in a certain gaol in the East where it was wont to break out year after year; and many others, since the days of Takaki--who first prevented it in the Japanese Navy as long ago as 1882--have by similar means prevented it. This is another example of the control that the use, in animal experiments, of human diets may exercise over results reached by the use of a single component of them, such as polished rice.

We have seen that if rats be fed on the perfectly constituted diet of the Sikhs they remain in good health: they do not, for instance, develop stone in the urinary tract. But if one removes from this diet the milk and milk products and cuts down the fresh vegetable foods to a minimum, then many of them do develop this condition. They develop also a wide variety of other ailments, but it is with 'stone' that I am here concerned. If we replace the milk or butter they do not develop this condition. This is an observation of great importance to the wheat-eating races of northern India, amongst whom 'stone' is so

common. For it is precisely these articles of diet--milk, milk products and fresh vegetables--which the poorer classes amongst them have to cut out when times are hard. There are, no doubt, other factors concerned in the causation of 'stone'; but the broad fact remains that a perfectly constituted diet rich in milk, milk products and fresh vegetable foods affords a high degree of protection against it.

Variety of Disease in Improperly Fed Animals

I have mentioned the freedom from disease enjoyed by well-fed and hygienically housed albino rats. During the last eighteen years of my experimental work in India I used many thousands of animals--rats, pigeons, fowls, rabbits, guinea-pigs and monkeys--feeding them on diets not synthetically prepared from purified foodstuffs but from foodstuffs in common use by the people of India; my purpose, as previously hinted, being to learn what relation the food used by the people had to the diseases from which they suffered. At the risk of being tedious I shall now enumerate the maladies I have encountered in these improperly-fed animals, leaving out of count such manifestations of ill health as weakness, lassitude, irritability and the like, which are commonly met with in malnourished animals. Here is the list. *Skin diseases:* loss of hair, gangrene of the feet and tail, dermatitis, ulcers, abscesses, oedema. *Diseases of the eye:* conjunctivitis, corneal ulceration, xerophthalmia, panophthalmitis, cataract. *Diseases of the ear:* otitis media, pus in the middle ear. *Diseases of the nose:* rhinitis, sinusitis. *Diseases of the lungs and respiratory passages:* adenoids, pneumonia, broncho-pneumonia, bronchiectasis, pleurisy, pyothorax, haemothorax. *Diseases of the alimentary tract:* dental disease, dilatation of the stomach, gastric ulcer, epithelial new growths in the stomach (two cases of cancer), duodenal ulcer, duodenitis, enteritis, colitis, stasis, intussusception and a condition of the lower bowel suggestive of a pre-cancerous state. *Diseases of the urinary tract:* pyonephrosis, hydronephrosis, pyelitis, renal calculus, nephritis, urethral calculus, dilated ureters, vesical calculus, cystitis! incrusted cystitis. *Diseases of the reproductive system:* endometritis, ovaritis, death of the foetus in utero, premature birth, uterine haemorrhage testicular disease. *Diseases of the blood:* anaemia, a pernicious type of anaemia, Bartonella muris anaemia. *Diseases of the lymph and other glands:* cysts, abscesses, enlarged glands. *Disease of the endocrine glands:* goitre, lymph-adenoid goitre, adrenal hypertrophy, atrophy of the thymus, haemorrhagic pancreatitis (very occasionally). *Diseases of the heart:* cardiac atrophy, cardiac hypertrophy, myocarditis, pericarditis, hydropericardium. *Diseases of the nervous system:* polyneuritis, beri-beri, degenerative lesions. *Diseases of bone:* crooked spine, distorted vertebrae (no work was done on rickets--a known 'deficiency disease'). *General diseases:* malnutritional edema, scurvy, prescorbutic states.

All these conditions of body, these states of ill health, had a common causation: faulty nutrition, with or without infection. They are the clinical evidence--the signs and symptoms--of the structural and functional changes in organs or parts of the body that result directly or indirectly from faulty nutrition. It will be noted that local infections and maladies of a chronic and degenerative kind are conspicuous amongst them. These maladies are, in short, the symptoms of malnutrition as observed in animals fed on faulty diets--some of them admittedly very faulty--in use by human beings, or on food-materials in use by them. It is reasonable, then, to expect that maladies of a similar order are likely to result from malnutrition in human beings. In my next lecture I shall endeavour to make

clear how it is that food of improper constitution leads to that disturbance of structure or function of organs or parts of the body which is 'disease'.

II

RELATION OF CERTAIN FOOD ESSENTIALS TO STRUCTURE AND FUNCTIONS OF THE BODY

In my first lecture I confined myself to the more general aspects of the relation of food to nutrition and of both to health and disease. To-day I propose to deal in more detail with those essentials that are needed for the efficient construction and maintenance of the fabric of the body and for the regulation of its processes. It is necessary to be aware of the different parts these substances have to play in nutrition and of the effects of their inadequate supply or inadequate utilization when supplied in sufficient quantities. For then only can it be understood how such inadequacy leads to that disturbance of structure or function of organs or parts of the body which is 'disease'.

These essentials are proteins, mineral elements and vitamins. But before dealing with them something must be said of oxygen and water.

Oxygen and Water

Strictly speaking both oxygen and water are to be regarded as foods, for of all the supplies on which the cells of the body are dependent they are the chief. The continued and unhampered supply of *oxygen*--avallable in the air we breathe--is, as you know, essential to the continued activities of the body. Respiration depends upon it; tissue-respiration as well as respiration in its commonly understood sense. So also does combustion, both of organic materials ingested as food and of certain substances that result from cellular activity. By its means the latent chemical energy of food is converted into other forms of energy for the work--both internal and external--of the body, and the waste products of that work are burned up and disposed of. Thus, the non-volatile substance--lactic acid--produced during muscular work, is burned to the volatile carbonic acid which is carried away by the blood and exhaled through the lungs. Without the adequate supply of oxygen the body would become clogged by the accumulation of waste. It is not possible here to discuss the manifold activities of oxygen in the body nor, indeed, is it necessary to do so. It suffices to emphasize the great importance of the efficient oxygenation of the tissues in maintaining the efficiency of the function of nutrition. The proper ventilation of the lungs and the proper exercise of the body are obvious means to this end. These means are complemental to the use of properly constituted food on which, also, the adequate supply of oxygen to the tissues depends.

Water is of outstanding importance to the body, both from the point of view of structure and of function. It is the most abundant constituent of living cells. Its presence therein

permits of changes in their form and of their return to their original form after alteration by movements; rapid displacements of substance and the mobility of living matter are thus rendered possible. Its conservation of the boundaries of ceils and their restoration after displacements due to motion conserve in their turn the minute internal structure of cells.

Although about two-thirds of the fabric of the body are made up of water, it is not present in all tissues in the same amount. Fatty tissue and bone contain less, the grey matter of the brain, glandular organs and muscle contain more, and the body fluids (blood, etc.) most. The percentage of water is highest in those tissues wherein chemical changes are most rapid, and in tissues that are called upon to function most frequently. The great importance of an adequate supply of water for infants and growing children, in whom metabolic processes are most active, is thus made evident.

Water is the solvent of most of the constituents of protoplasm; it is the vehicle that transports nutrients to the ceils, the medium wherein all chemical changes take place within them and the solvent wherein the end-products of these chemical changes are discharged from the body. The evaporation of water from the lungs and skin is one of the chief factors in the regulation of body temperature. It has, too, various mechanical functions such as in facilitating the movements of mobile parts (for example, joint surfaces and coils of intestine) one upon another. The functional efficiency of the digestive tract, the normal production of the digestive juices, the normal absorption of food and the normal action of the bowels may be cited as conspicuous examples of the need of the body for an adequate supply of water.

Water is constantly being discharged from the body by way of the skin (perspiration), lungs (exhalation), kidneys (urination) and bowel (defaecation). This loss is partly replaced by the water contained in solid food and by that produced in the chemical reactions of metabolism. But over and above this more than a quart, as such or in beverages, is needed dally to make good the loss. The need of the cells and tissues for water is expressed in that indefinite sensation which we call 'thirst'. The first rule in dietetics is to drink water in abundance.

The insufficient ingestion of water gives rise to headache, loss of appetite, disturbance of digestive functions and of the action of the bowels, nervousness and impaired capacity for work, mental or physical. In infants the loss of water consequent on diarrhoea, vomiting or excessive evaporation from the lungs may cause serious symptoms: fallure of digestive processes consequent on diminished production of the digestive juices, rapid loss of weight, dry skin, exhaustion, coma and convulsions.

Proteins

Proteins are the next most abundant constituents of living cells. Their chief role in the body is to provide materials for its growth and for the repair of its tissues. There is a constant utilization of proteins in these ways, a continual voiding of the waste products of their metabolism. Their continuous supply is, therefore, necessary; and this supply must be of the right kind, to furnish the requisite amino-acids from which the tissues of various parts of the body are built up. Besides their function as providers of building-materials they also furnish a certain amount of energy. They are the source from which the body elaborates certain enzymes, or ferments, such as those concerned in the digestive processes, and catalytic agents--glutothione, thyroxine, adrenaline and insulin--needed

for the speeding up of chemical processes.

The daily requirements of the body for proteins are approximately 1.0 gramme per kilogramme of normal bodyweight; more than this is an undesirable excess. Sources of them amongst animal foods are milk, meat, glandular organs, eggs and fish; and amongst vegetable foods, legumes, whole cereal grains, seeds, nuts and green vegetables. Those derived from animal sources are, in general, more suited to the needs of the human body than those derived from vegetable sources. The former are, in consequence, sometimes spoken of as 'good', 'suitable' or 'first-class' protein, and the latter as 'second-class' protein. But it is not necessary that the protein requirements of the body should be derived chiefly from animal sources; it suffices if one-third of them be so derived. Nor is it necessary that 'good' protein be derived from 'meat'. Those of milk are amongst the best of all proteins and well able 'to leaven the whole lump' of those derived from vegetable foods. For this reason, amongst others, presently to be referred to, the use of milk and cheese as articles of diet, should be greatly extended. Much greater use should also be made of the better class vegetable proteins, such as those of soya bean, legumes and nuts, and-much less use of the flesh of animals. Apart from every other consideration the use of meat as the main source of proteins is as uneconomical as it is unnecessary; but where flavour is there will desire be also.

It will be obvious from these considerations that the insufficient ingestion, absorption or assimilation of proteins, or of proteins of the right kind, will tend to degradation of vital processes; a degradation manifested in stunting of growth, poor physique, lack of energy, resource and initiative, digestive disturbances and impaired action of glandular organs. To these there may be added a lowered resistance to infection. Severe degrees of protein-starvation, associated as they often are with want of food in general, may give rise to a condition known as 'malnutritional oedema', 'war oedema' or 'famine oedema' in which the body, in part or in whole, becomes waterlogged.

Mineral Salts

The mineral constituents of food consist of some twenty elements of which eleven--previously enumerated (chap. I)--are definitely known to be essential to vital processes. They are all intimately related one to another by complex chemical combinations and interactions, so that it is difficult to separate the functions of one from those of another. In general these functions are to provide building materials for the fabric, and to regulate various functions, of the body. In fulfilment of the first function some enter into the composition of all cells while others form the major part of the skeleton and teeth. In fulfilment of their regulating functions they have various parts to play: all are concerned in controlling the normal exchanges of body-fluids and the permeability of the cell membranes; some maintain and regulate the neutrality of the blood, others the normal contractility of muscles and excitability of nerves; some enter into the composition of the digestive juices; others take part in the transport of oxygen from the lungs to the tissues and of carbon dioxide from the tissues to the lungs, thus making oxidation processes possible. Indeed, it may be said that the more the mineral constituents of food are studied, the more important is their role in nutrition found to be. It is essential to remember this importance in view of the prominence which nowadays is given to vitamins--the one class of substances is as important as the other.

Mineral substances are continually being lost by the body by way of the excretions, and

their replacement is constantly necessary. Thus, in certain circumstances, the loss of salt may be excessive and give rise, if not replaced, to distressing symptoms. Herbivorous animals, and those human beings whose food is vegetarian, require more salt than carnivore or flesh-eaters.

From the point of view of dietary construction, four of these mineral elements--calcium, phosphorus, iron and iodine--are of outstanding importance; not only because of their own functions but because they are those most likely to be present in the average diet in insufficient quantities. In constructing diets the amounts of these minerals should be adjusted with the same care as is given to those of proteins, carbohydrates, fats and vitamins; and, in estimating the quantities of essential components in any diet, the calculations should always include these four elements. By making provision for their ample supply no serious deficiency of any other mineral essential is likely to arise.

Calcium.--Calcium is one of the most important, as well as most widespread, of all constituents of the body. It is a chief constituent of the bones and of the teeth. It controls the contractility of muscle including that of involuntary muscles such as those of the gastro- intestinal tract. The rhythmic beat of the heart depends to a great extent upon it, as do the movements of cilia *(vide infra).* It maintains the normal response of the nerves to stimuli, preventing their hyper-irritability, preserves the clotting power of the blood, and sustains the capillary circulation. It co-ordinates the activities of certain other mineral elements.

Calcium is made use of in the body to the extent of about 0.68 gramme daily; but to allow a fair margin for waste and non-absorption the food should provide at least a gramme a day. The allowance for expectant mothers and for growing children should be even greater. The growth of the bones and teeth as well as of the body generally, menstruation, pregnancy and lactation make special demands for its abundant supply, more especially in western countries where sunshine is scanty and the intake of vitamin D--a substance controlling the absorption and utilization of calcium--is low.

The insufficient supply of calcium in the food is one of the commonest of all food-faults in this country. Indeed, it is difficult for the growing child, under modern conditions of life and food-supply, to obtain enough calcium unless the diet contains at least a pint of milk a day-- milk being a rich source of it. This is another cogent reason for the greater use of milk as an article of diet. The diet of pregnant women is often dangerously low in calcium. Recent researches in America have shown that such women need 1.6 grammes dally: often they do not receive more than one-half of this amount. Its deficiency leads to the imperfect building of bones and teeth, in growing children to rickets and all its attendant consequences, to malformation or mal-alignment of the vertebrae and spinal curvature, and to decay of teeth. To satisfy the urgent demands for this important element elsewhere it may be withdrawn from the bones--its storehouse in the body. Not infrequently the normal calcium content of the blood, on which so many bodily activities rely, is being maintained at the expense of decalcification elsewhere--of teeth, alveoli and bones. The clinical expressions of such decalcification are softening of bone, weakness of bone, increased liability to fractures, retraction of the alveoli in which the teeth are set, and dental decay. Want of calcium leads also to nervous excitability and to a condition known as tetany, to impaired muscular activity, both of voluntary and of involuntary muscles, and to disturbance of cardiac rhythm and of the neutrality of the blood; it may also be a cause of chilblains and of irritability of the skin. Foods rich in

calcium are milk, cheese, turnip-top greens, black treacle, almonds, watercress, egg-yolk, peas, beans and green leafy vegetables of various kinds.

Phosphorus.--Phosphorus is an essential component of the nuclei of all cells. It therefore plays a conspicuous part in all cellular activities. It enters largely into the composition of the bones and teeth, and is needed for the manufacture of the lipins which abound in all tissues, and more especially in the nervous tissues. It should be provided in the diet to the extent of about 1.5 grammes daily--alike for women and children as for men--and for the same reasons as for the abundant supply of calcium. During pregnancy the amount should be increased, according to recent findings, to as much as two grammes daily.

Deficiency of phosphorus may lead to stunting of growth, poor bone formation, softening of bone, a certain type of rickets, tooth decay, disturbance of the normal neutrality of the blood and to depression of vital processes generally. Foods rich in phosphorus are cheese, egg-yolk, lean meat, almonds, nuts, whole wheat, liver, milk, fresh beans, spinach, brussels sprouts and potatoes.

Iron.--Iron is an essential constituent of the nuclei of all cells, and as such it is concerned in the control of all cellular activities. It is an essential constituent of the red pigment--haemoglobin--of the blood. Haemoglobin is the carrier of oxygen from the lungs to the tissue-cells; it is obvious, therefore, that iron in this, if in no other, capacity plays a vital part in the economy of the body. The daily loss of iron is from seven to eight milligrammes by way of the faeces and about one milligramme by way of the kidneys. In all there are lost about ten milligrammes daily, or about one-three hundredth part of the total haemoglobin--iron in the body. It has been estimated that the iron content of the average diet in this country is rarely more than ten milligrammes, while it is frequently as low as five. In these circumstances, ill health is likely to arise. This takes the form of anaemia, which, as is now known, is a common ailment, especially in infants and in women of the childbearing period of life; in the former, because of the plaucity of iron in the mother's or in cow's milk; in the latter, because of its insufficient ingestion or assimilation.

The diet should contain at least fifteen milligrammes of iron daily. During pregnancy this amount ought to be increased to twenty milligrammes. Foods rich in iron are lentils, egg-yolk, liver, beans, black treacle, oatmeal, whole wheat, turnip tops, spinach, prunes, dates and raisins. It is to be noted that milk is poor in iron. Nature compensates to some extent for this defect in milk by bringing the child into the world with a fair store of iron in its own tissues; but this store does not always protect the infant from anaemia when the mother's milk is poor in iron or when the child is fed on cow's milk.

Iodine.--Iodine is an essential constituent of the thyroid gland--its chief storehouse in the body--and of the active principle of the gland, thyroxine. It is necessary for the normal functional activity of this important organ whose action is to the oxidation processes of the body not unlike that of the bellows to the fire--thyroxine speeds up the rate of these processes. In normal circumstances, the daily requirements of iodine are about fifty *gamma* (1/1000th of a milligramme). Growing children, pregnant and lactating women, need more of it than others. More also is needed when the diet is rich in fats or contains an excess of lime, and more in some conditions of insanitation, of infection as of the intestinal tract and, indeed, of infections generally. Its deficiency in the diet admits of the operation of certain agents causing goitre: a malady likely to give rise

to cretinism, deaf-mutism and idiocy in the offspring of goitrous women. In regions where goitre is endemic, the iodine-content of water-supplies and locally produced foodstuffs is low. Rich sources of iodine are sea-foods and cod-liver oil.

Other important mineral elements are magnesium, copper, chlorine. fluorine and sulphur. The first has important physiological functions, particularly in relation to the movements of body-fluids. The second is invariably present in the brain and has a relation to the blood, being complemental to iron in the prevention of anaemia. The third (chlorine) plays a leading part in the alkali chlorides of the blood and tissues and in the hydrochloric acid of the gastric juice. The fourth (fIuorine) is a normal constituent of bones and teeth; it is not devoid of significance in the formation of these tissues. The fifth (sulphur) in the form of the complex amino-acid, cystine, is essential for growth, is a constituent of certain catalytic agents, and has a relation to the nutrition of joints.

It is commonly believed that if the foodstuffs of which a diet is composed be varied enough, there is little likelihood of deficiency of any important mineral elements. This is no doubt true; but the variety is often not sufficiently great nor of a kind to ensure an adequate supply of them. In this connection I quote the following from the *British Medical Journal* of 29th December 1934: 'The average diet in this country contains from 5 to 10 mg. of iron.' It is apparent, therefore, that the average diet is not varied enough to provide a sufficiency of this most important element, nor is it always varied enough to provide a sufficient amount of lime. The truth is that the common belief--safety in variety--is likely to be misleading; for, as McCollum showed years ago, one can ring the changes on a great variety of foodstuffs--muscle meats, cereal grains, tubers, roots, potatoes, peas and beans--and yet have fallure of nutrition unless the diet contains a sufficiency of the protective foods--milk and green leafy vegetables. This applies to vitamins as well as to mineral elements.

The Vitamins

The vitamins, according to present knowledge, are of five classes, designated by the letters of the alphabet: A, B, C, D, and E. Each has its own part to play in nutrition--a part that cannot be taken by any other.

Vitamin A.--Vitamin A is essential to growth and development of the young and 'to the orderly progression of nutritional processes at all ages' (Sherman). It is essential to the young in the way that without a sufficient supply of it pathological states are likely to arise and to interfere with growth and development. It is a promoter of vigour and stamina, and plays a part in maintaining the structure and function of the nervous system. It is one of the most important of the food essentials concerned in the efficiency of the function of reproduction and the rearing of the young; hence the importance of its adequate supply to pregnant and nursing women. It is a potent factor in maintaining the resistance of the body to infection. This it effects by its specific relation to epithelia throughout the body: that of the skin, of the mucous membranes (particularly of the respiratory and the alimentary tracts), of the glands of external secretion and their ducts, of the thyroid, the interior of the eye, the lungs, the kidneys, the bladder and all passages leading to the exterior of the body. Its deficiency gives rise to structural changes in epithelium which impair its functions and lower the local defences against infection. In this sense, and in this sense only, it is anti- infective. Diminished resistance to local infection may be the first evidence of its deficiency, and the pathological state resulting

therefrom the first clinical evidence that nutrition is at fault. Much more of it is needed for the prevention of infection than for growth. Let me draw your attention to the kind of change that is brought about in epithelium by lack of this vitamin. (A picture showing in cross-section the mucous membrane of the upper respiratory passage of a rat was here exhibited.) This membrane is covered by tall epithelial cells, each of which has a fringe of cilia. A function of these cells is to secrete mucus which not only traps bacteria but permits the cilia to perform their movements--this they can only do when the membrane they fringe is moist and the moisture contains calcium. The function of the cilia is, by their rapid movements in waves, to propel bacteria or foreign particles, as of dust, towards the exterior of the body, whence, in normal circumstances, they are ejected. It has been estimated that the cilia move at the rate of about 600 times a minute. Now when the food is deficient in vitamin A the cilia slough off and the cells themselves lose their secretory character, becoming horny or keratinized, as it is called. Figure to yourselves what this means: no longer is this trapping, this propelling of harmful particles, whether of dust or bacteria or both, possible in the areas so affected. For, unless the deficiency be very grave, it is only at certain places that these changes occur. Where they do occur the local defences are broken down and bacteria are free to implant themselves in the soil thus made ready for them and to invade the tissues. And it is a curious fact that, in these circumstances, bacteria that may otherwise exist as harmless saprophytes often take on pathogenic properties and become disease-producing. Mark how serious a view the body takes of these events: at once it sends up defence forces in the form of round cells to man the breach, and these may accumulate to such an extent as actually to form adenoid-like outgrowths.

The maladies resulting from deficiency of vitamin A are, with the exception of night-blindness, usually the result of superimposed infection. They involve, singly or in combination, many systems of the body: ocular, nervous, cutaneous, buccal, dental, gastro-intestinal, urinary and reproductive. Such diverse conditions as xerophthalmia, pneumonia, colitis) stomatitis, gastric ulcer, one form of goitre and stone-in-the-bladder may arise in consequence of its inadequate supply in the food of rats. Some of these conditions, such as xerophthalmia night-blindness, stomatitis, catarrhs of all sorts, and certain skin affections are definitely known to occur also in man from this cause; and, for my own part, I do not doubt but that the future will reveal a number of others that are due also to this cause in man: disease of the respiratory and gastro-intestinal tracts in particular. It is to be emphasized that many of the local maladies brought about by deficiency of this vitamin are often, because of the local infection associated with it, not readily curable by the provision of the vitamin; the reason no doubt being that pathogenic organisms, once they have taken root, are difficult to eradicate, especially in parts of the body where structural and functional changes have taken place. The fact that the administration of the vitamin by the mouth may not cure a certain condition is, therefore, no sufficient reason for the supposition that its deficiency may not have been a cause of it. Sub-optimum supply of vitamin A may be associated with no clinical signs of disease, depending on the degree of the deficiency, the age of the subject and the absence of infection. It may, indeed, be only by the sense of well-being, resulting from its more abundant provision, that its sub-optimum supply becomes apparent. As Sherman says of it: 'Its bountiful supply is a bulwark against disease of many kinds, a promoter of vigour, stamina, and that condition of body and its various parts and functions which conduces to

efficient and prolonged life.'

Rich sources of Vitamin A or of its precursor (carotene) are animal fats, cod liver oil, milk, butter, liver, eggs, herrings, carrots and fresh, green vegetables.

Vitamin B.--Vitamin B is a complex, said to consist of some five or six fractions, each having its own particular function. Their separation is largely a laboratory manoeuvre--a feat rarely indulged in by Nature, though some foodstuffs contain more of one fraction of the complex than of others. It is enough for the layman to know what are the chief functions of two of its principal parts: vitamin B_1 and vitamin B_2 (the latter itself a complex). Both are essential for growth (Fig. 4); one (B_1) is destroyed by heat; the other (B_2) is not.

Vitamin B_1 is intimately concerned with the maintenance of neuromuscular efficiency throughout the body, such, for instance, as that of the stomach, the colon and the heart. Within an hour of the administration of a dose of the International Standard Preparation of the vitamin to a person whose diet is low in this factor, but who may show no obvious sign of its lowness, the heart's action is markedly improved and remains so for approximately four hours, when the good effect wears off. If, however, the same dose be given to a person whose diet contains enough of it, no effect on the heart is observable on electro-cardiographic examination. In animals (pigeons and rats), under experimental conditions, its deficiency gives rise to marked slowing of the heart's action (bradycardia) amounting sometimes to 'heart-block'. It causes also a slowing down of respiration and a fall in body temperature and in blood pressure. Its deficiency has a specific effect on the adrenal glands (causing them to undergo hypertrophy) and through them, as well as more directly, on the sympathetic nervous system. Appetite is dependent in great measure, on an adequate supply of it--appetite for water as well as for food. It has an important influence on the secretory activity of the stomach, its deficiency greatly impairing the production of gastric juices. In its absence or inadequate supply the muscular movements of the stomach and of the lower bowel are much impaired. This impairment of the secretory and motor functions of the stomach deranges the function of nutrition at its very outset. It also influences nutrition in a number of other ways. Thus it promotes the assimilation of food and the multiplication of cells (growth). An interesting example of the latter is afforded by the developing chick's intestine when grown *in vitro.* Explanted, about the eighteenth day of development, in normal fowl plasma, it grows profusely; but when explanted in plasma from a fowl fed on polished rice--which is deficient in this vitamin--growth is scanty or altogether inhibited. Further, if the vigorously growing tissue be transferred from the normal to the deficient plasma, growth immediately ceases and the young cells undergo rapid disintegration. It is notable that intestinal tissue is particularly sensitive in this respect--a fact which can scarcely be without significance in relation to the immature gastro-intestinal tract of infants.

Amongst other effects of want of this vitamin are degeneration of lymphatic tissue, atrophic changes in the spleen and sex glands, disturbance of carbohydrate metabolism, reduction of the glycogen normally stored in the liver and the accumulation of a toxic substance (lactic acid) in certain tissues which may cause functional paralysis and convulsive seizures. Beri-beri is always associated with deficiency of this vitamin, though the vitamin deficiency is not always followed by beriberi; the deficiency is not the only factor concerned in its causation. Beri-beri is rarely encountered in this country; but it is not unlikely that other forms of neuritis, such, for instance, as alcoholic neuritis, may

be due as much to inadequate absorption of vitamin B_1 consequent on derangement of digestive processes, as to toxic action.

To see Figure 4 full-sized, click here.

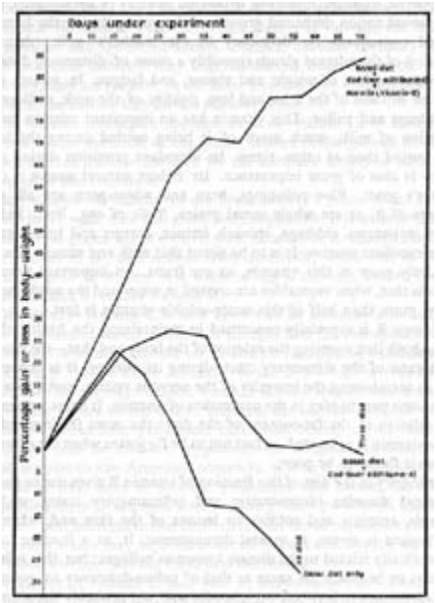


Figure 4. Effect on the growth and mortality of young rats of adding vitamins to a basal diet devoid of them but otherwise complete

The insufficient ingestion of vitamin B_1, is a common food fault, due mainly to the extensive use of vitamin-poor or vitamin-less carbohydrate foods, such as polished rice, white flour and sugar. It has to be remembered in this connection that the more carbohydrate eaten the more vitamin B_1 is required. The effects of its inadequate provision are loss of appetite, impaired digestion, decreased motility of the stomach, sluggish bowel action, impaired growth of the young during the lactating period consequent on deficiency in the mother's milk, deranged function of the adrenal glands (possibly a cause of distressing dreams), nervousness, loss of weight and vigour, and fatigue. In infants there may be stiffness of the arms and legs, rigidity of the neck, restlessness, fretfulness and pallor. This vitamin has an important relation to the secretion of milk, much more of it being needed during the lactation period than at other times. Its abundant provision during pregnancy is also of great importance. Its richest natural source is dried brewer's yeast. Rice polishings, bran and wheat-germ are all good sources of it, as are whole cereal grains. Yolk of egg, liver, kidney, heart, watercress, cabbage, spinach, lettuce, carrots and tomatoes are other excellent sources. It is to be noted that milk and muscle meat are relatively poor in this vitamin, so are fruits. An important practical point is that, when vegetables are cooked in water and the water thrown away, more than half of this water-soluble vitamin is lost.

Vitamin B_2 is especially concerned in maintaining the health of the skin--both that covering the exterior of the body and that--the mucous membrane of the alimentary tract--lining its interior. It is concerned also in maintaining the integrity of the nervous system, and appears to have some part to play in the prevention of anaemia. It bears a quantitative relation to the fat-content of the diet: the more fat ingested the more vitamin B_2 is needed--a fact not to be forgotten when the digestion of fats is found to be poor.

Deficiency in the diet of this fraction of vitamin B gives rise to gastrointestinal disorder (degenerative and inflammatory states, such as gastritis, enteritis and colitis), to lesions of the skin and, when the deprivation is severe, to mental derangement. It, or a fraction of it, is specifically related to the disease known as pellagra; but this relation appears to be much the same as that of iodine-deficiency to goitre or of B_1--deficiency to beri-beri--it is not the sole, nor probably the ultimate, cause. Of far greater importance is it to keep in mind that a generous provision of vitamin B_2 is one of the factors on which the health of the skin, the gastro-intestinal tract and the nervous system depends. In rats under experimental conditions, cataract has been observed to result from its want.

It is not yet definitely known whether it is the B_1 or the B_2 fraction of the complex which contributes so markedly to the prevention of microbic invasion of the body. This is not a matter of great practical importance, so long as it is recognized that vitamin B does play a part in this connection. Many years ago I showed that, in animals fed on food deficient in vitamin B, bacteria were apt to find their way through the walls of the intestine into the blood-stream. Further, bacteria normally absent from the small intestine may migrate thereto from the colon where, normally, they are present; in the latter location they are harmless, even useful, in the former they have a noxious action.

The vitamin B-complex appears, as does vitamin C, to have some relation to the nutrition of the joints. Recent investigations in regard to rheumatism indicate the need for the adequate supply of both these vitamins in this condition.

Rich sources of vitamin B_2 are dried brewer's yeast, liver, kidney, muscle meat, eggs, milk and green leafy vegetables. It is to be noted that whole cereal grains are in general poor sources of B_2 though relatively rich sources of B_1, that muscle meat and milk, while rich in B_2 are relatively poor in B_1, and that white of egg is the only known food in which vitamin B_2 occurs without B_1.

Vitamin C--Vitamin C is now known to be identical with ascorbic acid--a potent reducing agent. It is thought that the biological activity of ascorbic acid may depend on its double function of oxidation and reduction. If this be so its deficiency in the diet would involve the depression of oxidation processes. Vitamin C has a specific relation to the supporting tissues of the body, 'enabling the cells to produce and to conserve inter-cellular substances that cause setting of the matrix in which the cells lie and are supported'--an enlightening observation which we owe to two American observers. It is as if the bricks of which a house is built were to produce substances that caused the mortar supporting them to set, and went on doing so to prevent its upsetting. This function has a particular concern for the blood capillaries; the cells comprising which may become loosened in their settings for want of it and blood extrude between them into the tissues.

Deficiency of vitamin C may lead to haemorrhages in various parts of the body, to sallowness and other affections of the skin, to fragility of bones, swelling of joints, imperfections in the teeth, unhealthy gums, congestion of the bladder, changes in the

bone-marrow, gastro-intestinal disorder (such as duodenal ulcer--in guinea-pigs), and to latent or manifest scurvy. Like vitamin B it has a specific relation to the adrenal glands--its chief storehouse in the body--which undergo enlargement when it is deficient in the diet. This observation, which I made in 1919, calls to mind the enlargement of the thyroid gland--the chief storehouse of iodine in the body--which results from deficiency of iodine. Like proteins and vitamins A and B, but in its own particular way, vitamin C has an anti-infective action. It has, for instance, recently been shown that guinea-pigs, fed on diets poor in vitamin C but not sufficiently lacking in it to cause manifest scurvy, develop the symptoms characteristic of rheumatic fever when streptococci, isolated from cases of this disease in human beings, are administered to them; guinea-pigs receiving diets rich in vitamin C do not, or only in relatively few cases, develop these symptoms when similarly treated. The same appears to be true of intestinal tuberculosis: a high proportion of those receiving too little vitamin C develop tuberculous ulceration of the intestine when virulent tubercle bacilli are administered to them by the mouth, while only a small proportion of those receiving abundance of vitamin C develop this condition when similarly treated. These observations in guinea-pigs may prove to be of significance in regard to rheumatism and intestinal tuberculosis in man; for man resembles the guinea-pig in this that he is equally sensitive to want of vitamin C.

Rich sources of vitamin C are parsley, orange peel, green chillies, cabbage, orange juice, lemon juice, brussels sprouts, caulifower and other green leafy vegetables. It is to be remembered that leafy vegetables rapidly lose a great part of their content of this vitamin as their freshness diminishes.

Vitamin D.--The function of this vitamin is to promote the absorption of calcium from the intestine and to assist in maintaining its normal level in the blood. It is a chief regulator of calcium and phosphorus metabolism and the fixer of calcium in the bones and teeth. Through this regulation it serves to ensure and to maintain the normal structure of the bony framework of the body and of the teeth. It is associated, in the control of calcium metabolism, with the parathyroid glands whose secretion is a mobilizer of calcium, releasing it as occasion demands or as exceptional circumstances determine from the bony structures of the body. The metabolism of calcium is thus controlled by a substance derived from food as well as by a substance manufactured by the body itself. The deposition of lime and phosphorus in growing bones is also related to a ferment--phosphatase--which is normally present in them.

This vitamin has an important relation to the bone marrow, helping to ensure the normal proportions of its cellular constituents. Its deficiency in the diet leads to mar-absorption of calcium from the intestine, to shortage of calcium in the blood, to the imperfect deposition of lime and phosphorus in the bones, and to the occurrence of rickets. The structure of teeth is similarly impaired by its want, with resultant dental decay. Enlargement of lymphatic glands in various parts of the body--neck, groin and axilla--may also result from its inadequate supply. Another malady to the causation of which deficiency of vitamin D contributes is osteomalacia; a condition in which great deformity of bones occurs. This malady is common in certain parts of India and China and is usually confined to women. A very important consequence of deformities of bone brought about in these ways is alteration in contour of the pelvis; it is one that may give rise to serious difficulties during childbirth. Chilblains may be caused by partial deficiency of this vitamin in association with calcium-insufficiency.

It is not known whether vitamin D has any special anti-infective action, though sufferers from rickets are very prone to certain infections, especially of the respiratory tract. Rickets of severe type is, happily, much less common in this country than formerly, although, as recently as 1928, it was stated that 90 per cent of elementary schoolchildren in London suffered from minor degrees of it.

The animal organism is endowed with the capacity to manufacture its own vitamin D following exposure of the body to the ultra-violet rays of the sun. Foods may also be activated in the same way or by artificial ultra-violet irradiation. Vitamin D is nowadays manufactured synthetically by the ultra-violet irradiation of ergosterol. The product is known as calciferol and is potent in very small dosage.

The sources of this vitamin are relatively scanty: cod liver oil, halibut and other fish oils, liver, kidney, butter and yolk of egg are the chief. It is, indeed, difficult in countries where sunshine is scanty for children to obtain enough of it unless the diet is fortified by the addition to it of cod liver oil or of calciferol. In the administration of the latter great care must be taken to avoid overdosage, the effects of which may be serious. Rickets is by no means unknown in the tropics, usually occurring in those castes observing the Purdah system.

Vitamin E.--Vitamin E is concerned in the maintenance of the functional efficiency of the reproductive system: a concern which it shares with protein, and with vitamins A and B. It is not yet clear that it has any very important part to play in this regard in human beings. It is widely distributed amongst foodstuffs; occurring in wheat germ, eggs, milk, meat, lettuce, spinach, watercress, coconut oil, cotton seed and a number of others.

Vitamins in General

It will be apparent from the foregoing facts that each vitamin has specific relations to certain structures of the body: vitamin A to epithelium and nerve; vitamin B to the gastro-intestinal tract, nervous system and skin; vitamin C to the cement substance that binds the cells of the body together; vitamin D to the bones and teeth; and vitamin E to the reproductive system. Their relations are not, however, confined to these: thus, one may support another in maintaining the health of the skin, the teeth, the bones, the gastro-intestinal tract, or the nervous system; and all are closely intertwined in their action with other essential constituents of the food. Consider, for example, the factors concerned in maintaining the structure and health of the teeth. There are, to begin with, the minerals--calcium and phosphorus--of which the teeth are mainly composed and of which an adequate supply must not only be provided in the food but adequately absorbed from the intestinal tract. There is the vitamin D needed to ensure both the proper absorption of calcium and its proper deposition--together with phosphorus--in the teeth. There is the vitamin C required to maintain the matrix in which the cells of the teeth lie. There are the vitamins A, C and B_2 needed for the maintenance of the health of the gums and alveoli in which the teeth are set. All of these are essential to the normal structure and health of the teeth, and deficiency of any one of them may give rise to dental decay. The dietetic causes of dental caries are, therefore, multiple (and not the least of these is the excessive use of sugar). The same is true of many other diseases of a degenerative kind in the causation of which malnutrition is concerned. For the maintenance of health of any organ or part of the body the adequate supply of all things needed for normal nutrition is necessary. It is true that the outstanding deficiency of one or other essential may give to

the resultant disturbances of structure or function characters which we recognize as specific disease entities, but even then default of other essentials may contribute to their production.

It is during the early and growing period of life that an optimum supply of all vitamins, as well as of other essentials concerned in the maintenance of structure and function of the body, is so necessary. For the foundations of disease are often laid by their inadequate provision in early life. This is particularly true of deficiency of vitamins A and B, which may leave behind them diseased states as of the gastro-intestinal tract--that subsequent administration of these vitamins by the mouth may be unable to remedy, though their parenteral administration may prove more effective. During pregnancy also--and lactation--an abundant supply of vitamins of every kind is needful, as well for the child as for the mother. Indeed, at all times optimum efficiency of the body and of its various functions depends, in great part, on an optimum supply of vitamins. Their function is not merely the prevention of the 'deficiency diseases'--xerophthalmia, beri-beri, pellagra, scurvy and rickets--with which they are usually associated by name; being called 'anti-this' or 'anti-that'. The use of these limiting descriptive terms--'antixerophthalmia', 'anti-beri-beri', 'anti-scorbutic' and so on--however well they may have served their purpose in the past, when we were largely groping in the dark, is, as I pointed out fifteen years ago, objectionable. For they concentrate attention on particular 'deficiency diseases' and convey the impression that all the vitamins have to do is to prevent them. Attention is thus diverted from their far more important relations to structure and functions of the body as a whole. All these specific deficiency diseases are associated in their origin with severe degrees of vitamin-deprivation. But outside the laboratory these severe degrees are encountered relatively rarely. Milder degrees are much more common; and, as far as vitamins A, B and C are concerned, bacterial or other pathogenic agents may, and often do, combine with these milder degrees of vitamin-deficiency to produce illnesses differing widely from the specific deficiency diseases with which the vitamins are commonly associated in the professional and lay mind. The inadequate ingestion of vitamin A does not, for instance, always cause xerophthalmia; infections of the lungs, skin or intestinal tract are often the consequences of it. So, too, with vitamin B: poor appetite, some digestive disturbance, nervousness, feeble action of the heart, lack of vigour and fatigue may be evidences of its inadequate supply, where no signs of beri-beri exist. Similarly, in regard to insufficiency of vitamin C, there may be no manifest signs of scurvy yet it may be present in a latent form, as that great authority on the subject--the late Alfred Hess-- assured us that it often is. No teaching could be more purblind, in the light of our present knowledge (incomplete though it be) of the important relations of the vitamins to structure and functions of the body, than that which affirms there is no insufficiency of vitamins A, B, C or D because there is no xerophthalmia, no beri-beri, no pellagra, no scurvy or no rickets. There may be no vitamin-insufficiency; on the other hand, there often is. I speak now of optimum health; not of that sub-optimal state of being which so many are content to regard as good health.

Since the year 1921 I have used every occasion to emphasize that it is the lesser degrees of vitamin-deficiency, and the less obvious manifestations of such deficiency that are of importance in Western countries. A recognition of this fact is, I believe, essential to the prevention and cure of many of the commoner sicknesses of mankind--sicknesses to which we cannot always attach a diagnostic label. 'It is rare', as I wrote in 1921, 'that the

food of human beings is totally devoid of any one vitamin; it is more usual for the deficiency to be partial, and for more than one vitamin to be partially deficient; it is more usual still for partial deficiency of vitamins to be associated with deficiency of suitable protein and inorganic salts and with an excessive richness of the food in carbohydrates. Consequently, the manifestations of disease resulting from the faulty food are compounded of the several degrees of avitaminosis on the one hand, and of ill-balance of the food on the other. Nor is this all, for pathogenic organisms present in the body, during the period of its subjection to the faulty food, contribute their share to the general morbid results. . . . Other factors also, such as age, sex, individual idiosyncrasy, rate of metabolism, fatigue, cold, insanitary surroundings, overcrowding, the varying susceptibilities of different individuals, of different organs and of the same organs in different individuals, all play a determining part in the production of the morbid result of food deficiency. So it is that in practice the manifestations of deficiency disease are influenced by a number of factors apart from the actual food fault. It maybe expected, therefore, that wide variations in the incidence, the time of onset, and the character of the symptoms will occur in human beings in whom the dietetic fault has been to all appearances the same. . . . It is to this variety of morbid change that I desire to draw attention . . . since it seems to me to impart to the term "deficiency disease" a wider significance than has been attached to it hitherto.' At the time these words were written they were received with some scepticism, yet to-day 'it is becoming generally recognized that much subnormal health and development, and even incidence of disease, are associated with a partial deficiency of one or more of the accessory substances'.*

If the knowledge acquired during the past quarter of a century is to yield its fullest fruit in the betterment of the national health it must be recognized that an optimum supply of all vitamins, in an otherwise well- balanced diet, is a prerequisite of optimum health; and that a minimum supply, while it may suffice for the prevention of certain specific 'deficiency diseases', creates the conditions preceedent to the occurrence of a wide range of other sicknesses.

All of which, in regard to vitamins, is not to minimize the great importance of other food-essentials in maintaining nutritional harmony and this, in its turn, the melody of health.

* Medical Research Council's Report on Vitamins, 1932.

III

NATIONAL HEALTH AND NUTRITION

To one whose work has lain in India, and who for more than twenty years has been engaged in a study of the relation of faulty food to disease, the belief that such food is of paramount importance in the causation of disease amounts to certainty. For there he meets with 'deficiency diseases' of every kind: xerophthalmia, night-blindness, beri-beri, malnutritional oedema, scurvy, rickets, osteomalacia, pellagra, angular stomatitis and certain skin diseases that are of this order. There, too, he encounters many maladies, not

usually regarded as of malnutritional origin, which experience, both in the laboratory and the field, teaches him to regard as wholly or in part of this nature: gastro-intestinal diseases of various kinds, including nonspecific colitis and peptic ulcer, certain respiratory diseases often found in association with xerophthalmia, urinary calculus, some ulcers and cardiac disorders, pyorrhea and a number of others. Further, he soon becomes aware--if he had not avallable for his enlightenment the testimony of many shrewd observers who have gone before him--that malnutrition is a chief cause of the lowered resistance to infection exhibited by so many of the Indian people; the chief reason why they succumb by hundreds of thousands to the ravages of such scourges as malaria, kala-azar, cholera, dysentery, leprosy and tuberculosis. For him the soil assumes an importance even greater than the seed, and he becomes impressed by the urgent necessity to render it inhospitable to the growth of the seeds of disease by adequate nourishment of the body.

If we look upon 'infection' of whatever kind, be it due to microbe, protozoa, metazoa, or invisible virus, or to the intervention of vectors of pathogenic agents, as the evidence of personal or environmental uncleanliness, then it may be said that the two chief causes of disease are faulty food and dirt. These two are the senior partners in the criminal business of disease-production--each the coadjutor of the other. It is along lines of improved cleanliness, both personal and environ mental, that the triumphs of modern medicine have lain; it is along lines of improved nutrition that greater triumphs still remain to be achieved. Some years ago I made the statement that 'the newer knowledge of nutrition is the greatest advance in medical science since the days of Lister. When physicians, medical officers of health and the lay public learn to apply the principles which this newer knowledge has to impart . . . then will it do for medicine what asepsis has done for surgery.' I see no reason, in these later days, to detract from this view; on the contrary, there is every reason to emphasize it the more, particularly in regard to preventive medicine.

In this country the conviction that faulty food, and the faulty nutrition resulting from it, is a principal cause of ill health, does not appear to be acquired so readily as it is in the tropics. Perhaps it is that as an island race we have no others, at close range, with whom to compare ourselves. The tribes of the Indian Frontier are far removed from the slums of our great cities; and it would be as difficult for the slum dweller to realize the perfection of physique to which these tribes attain, though nourished on the simplest and least varied kinds of foods, as it would be for the Frontier tribesman to understand that the physical imperfections of so many of the dwellers in the slums are largely due to the imperfections of the foods on which they are reared. Nevertheless, things nutritional are not, in essence, so different in India and in England as they may seem.

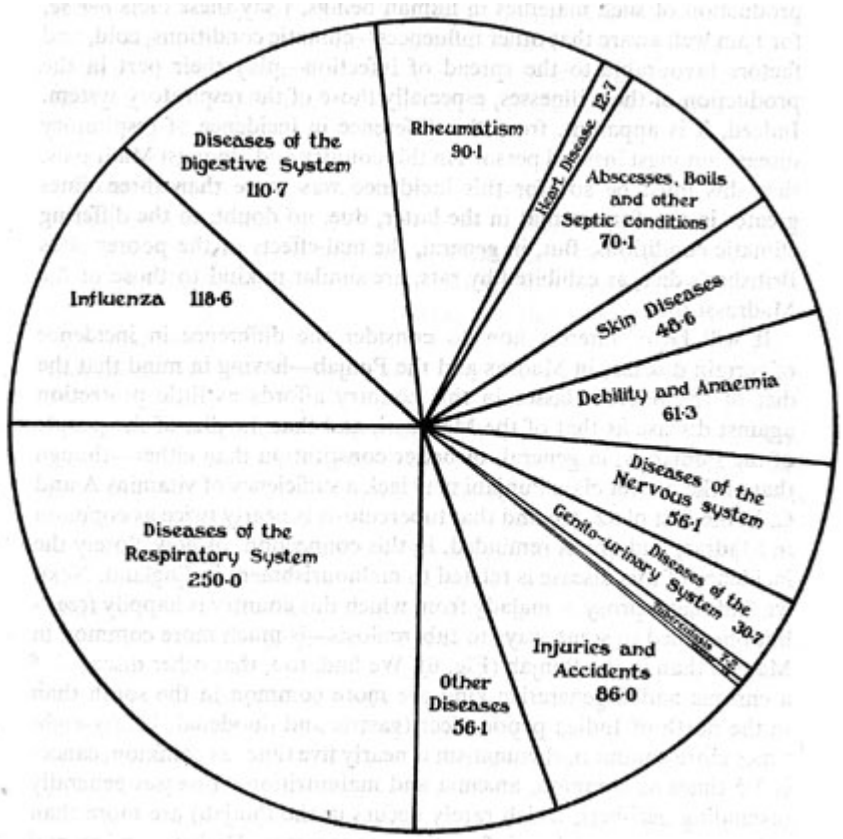


Figure 5. Insured persons in representative areas, urban and rural, in England and Wales--proportion per 1,000 cases of certain diseases to total cases treated by Insurance Practitioners, 1933. (Prepared from the Annual Report of the Chief Medical Officer of the Ministry of Health for the year 1933)

Diet and Incidence of Disease

Let me remind you of the experimental contrast to which I drew your attention in my first lecture (Fig. 3). You may remember that the great majority of the rats in that experiment enjoyed good health when fed on a well-constituted diet such as is used by Sikhs of the better class, while the great majority of those fed on an ill-constituted diet, such as is commonly used by the poorer classes in this country, developed two chief kinds of disease: respiratory and gastro-intestinal. You may remember also that the majority of rats fed on a diet in common use by the people of Madras also suffered from disease of these two systems of the body. The diet of the poorer class Britisher was, in fact, little or no better, so far as disease prevention was concerned, than that of the Madrassi. Here, now, is a diagram prepared from the material provided in the Annual Report of the Chief Medical Officer of the Ministry of Health for the year 1933 (Fig. 5). You will observe that amongst every 1,000 sick persons of the insured classes in England and Wales no less than 250 suffered from diseases of the respiratory system, and no less

than 110 from diseases of the digestive system. Diseases of these two systems of the body accounted for more than one-third of all illness in these classes of the community. A similar diagram, prepared from the Report (1933) of the Surgeon-General with the Government of Madras, reveals that amongst sick persons of the hospital class in Madras, no less than 183 out of every 1,000 suffered from diseases of the digestive system and 76 from diseases of the respiratory system; or more than one- quarter of the total sick. If from the calculation we remove the sufferers from purely tropical ailments, then in Madras also disease of these two systems of the body would account for approximately one-third of all sickness. I submit that if these diseases be, as they are, a chief consequence of feeding rats--living in an equable climate and as far as possible protected against infection or influences favouring it--on a diet in common use by the poorer class Britisher and, also, a chief consequence of feeding them on a diet in common use by the poorer class Madrassi, then these diets *per se* are likely to be favourable to the production of such maladies in human beings. I say these diets *per se,* for I am well aware that other influences--climatic conditions, cold, and factors favourable to the spread of infection--play their part in the production of these illnesses, especially those of the respiratory system. Indeed, it is apparent, from the difference in incidence of respiratory disease amongst insured persons in this country and amongst Madrassis, that this must be so; for this incidence was more than three times greater in the former that in the latter, due, no doubt, to the differing climatic conditions. But, in general, the mal-effects of the poorer class Britisher's diet, as exhibited by rats, are similar in kind to those of the Madrassi diet.

It will be of interest now to consider the difference in incidence of certain diseases in Madras and the Punjab--having in mind that the diet of the poorer classes in this country affords as little protection against disease as that of the Madrassi, and that the diet of the people of the Punjab is, in general, of better constitution than either--though that of the poorer class Punjabi may lack a sufficiency of vitamins A and C. In the first place, we find that tuberculosis is nearly twice as common in Madras, and one is reminded, in this connection, of how closely the incidence of this disease is related to malnourishment in England. Next, we find that leprosy, a malady from which this country is happily free--but one allied in some ways to tuberculosis--is much more common in Madras than in the Punjab (Fig. 6). We find, too, that other diseases of a chronic and degenerative kind are more common in the south than in the north of India: peptic ulcer (gastric and duodenal) is fifty-eight times more common, rheumatism is nearly five times as common, cancer is 3 5 times as common, anaemia and malnutritional diseases generally (excluding beri-beri, which rarely occurs in the Punjab) are more than twice as common; rickets is four times as common. Diabetes and mental disease are three times as common, disorders of the heart four times, nephritis ten times, and infestation by round worms twenty times as common in Madras, while ulcers, skin diseases and various other local ailments are all more common in Madras. These differences in the incidence of disease can, I think, be accounted for in large part by the difference in the nutritive quality of the diets of the two peoples, and in view of the poor quality of the diet of many of our own people. they are, to say the least of it, suggestive. They suggest that a similar relation of food of poor quality to the incidence of human ailments may be expected in other countries and in other peoples. That such a relation actually does exist elsewhere is exemplified by the studies made by Drs. Orr and Gilks of two African tribes whose diseases could be correlated with the defects of their diets and the incidence of these diseases with

differences in these defects. Indeed, the experiences of a number of skilled observers in Africa provide abundant evidence that, there also, improper quality of human food is a factor of fundamental importance in the causation of disease.

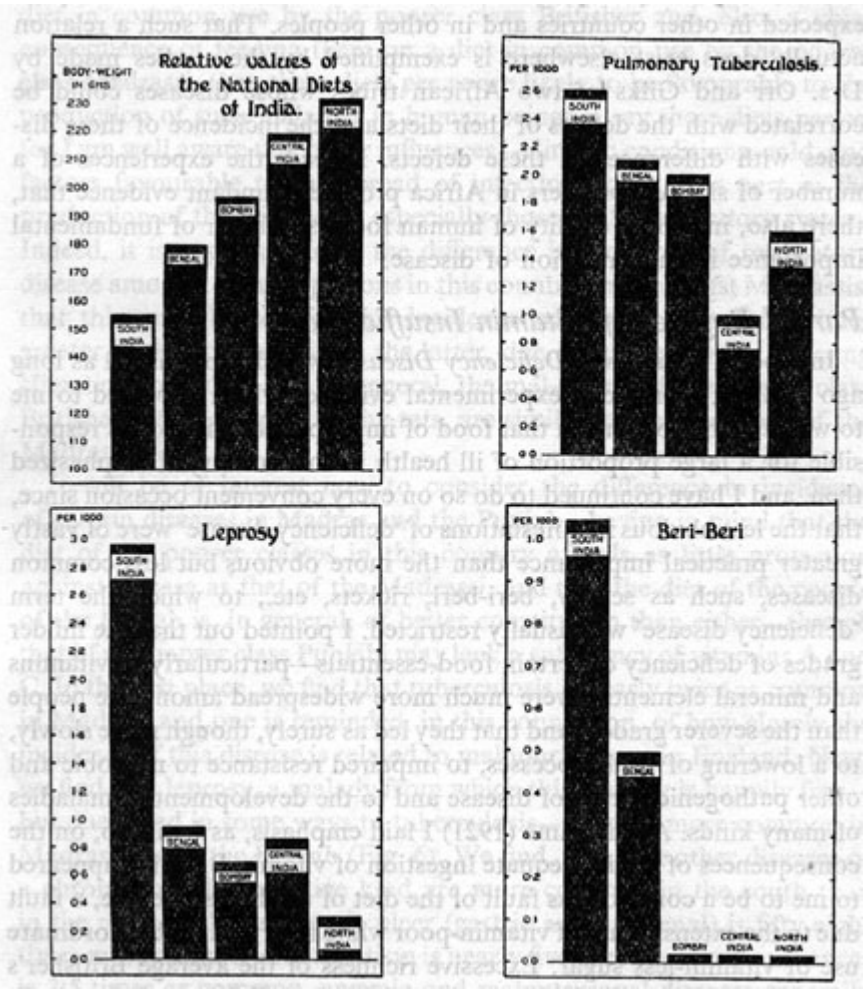


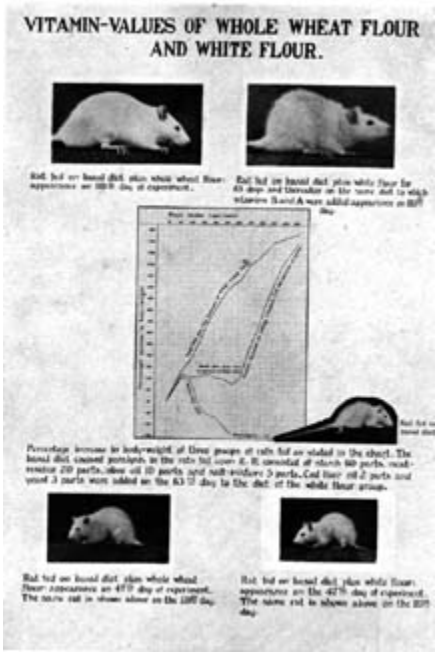
Figure 6. Nutritive values of diets in common use in the five main divisions of India (as determined by feeding experiments on rats) compared with the incidence of certain diseases per 1,000 of sick persons in these divisions.

Partial Degrees of Vitamin Insufficiency

In a book--*Studies in Deficiency Disease*--which I published as long ago as 1921, I provided experimental evidence which appeared to me to warrant the conclusion that food of improper constitution is responsible for a large proportion of ill health in this country. I emphasized then, and I have continued to do so on every convenient occasion since, that the less obvious manifestations of 'deficiency disease' were of vastly greater practical importance than the more obvious but less common diseases, such as scurvy,

beri-beri, rickets, etc., to which the term 'deficiency disease' was usually restricted. I pointed out that the milder grades of deficiency of certain food-essentials--particularly of vitamins and mineral elements--were much more widespread among the people than the severer grades; and that they led as surely, though more slowly, to a lowering of vital processes, to impaired resistance to microbic and other pathogenic agents of disease and to the development of maladies of many kinds. At that time (1921) I laid emphasis, as I still do, on the consequences of the inadequate ingestion of vitamin B_1, which appeared to me to be a conspicuous fault of the diet of the British people, a fault due to the extensive use of vitamin-poor white flour and to the inordinate use of vitamin-less sugar. Excessive richness of the average Britisher's diet in these two carbohydrates gives rise to insufficiency of vitamin B_1 for two reasons: the first, that the food as a whole does not contain enough of it, and the second, that relative to the richness of the diet in carbohydrates this vitamin is rendered still more deficient; for we now know that the greater the consumption of carbohydrates the more vitamin B_1 is needed. Consider, in this connection, the chart which I now show you (Fig. 7). It is self-explanatory and I need not, therefore, amplify its description. It illustrates, however, two things to which I would draw your attention: first, the inadequacy of white flour as compared with freshly-ground whole wheat flour; and second, the striking difference in appearance of rats fed properly from infancy as compared with those who in earlier life have been improperly fed and have to make up for lost time when properly fed at a later age.

To see Figure 7 full-sized, click here.



In this connection, also, let me draw your attention to the results of a large-scale experiment, carried out by Professor J. C. Drummond and his colleagues, to which he made reference in his Harben Lectures for 1933. This experiment was designed with the

object of learning whether or not mild degrees of vitamin B_1 deficiency gave rise to disease, when animals (rats) were fed for long periods on food having this fault but otherwise satisfactory. Speaking of the results of this experiment, and of the kinds of disease from which the animals suffered, he said: 'He (McCarrison) is unquestionably right in insisting that vitamin-deficiency--and it must be remembered that he stresses at every turn the importance of recognizing the widespread occurrence of mild deficiency--is directly or indirectly responsible for a very large proportion of ill health to-day.' And in his Lane Medical Lectures, a year later, he repeats with even greater emphasis the same assertion. It is not only amongst the poorer classes in this country, but also amongst those who are better off, that the diet is commonly excessively rich in vitamin-poor, mineral-poor starchy foods and in protein-less, vitamin-less, mineral-less sugar. It is impossible for people subsisting on such diets to remain in good health. 'It is only being gradually realized,' says Dr. Friend, whose recently published book, *The Schoolboy,* is so valuable a contribution to the problems of food and nutrition, 'that the deficiency of white bread in vitamin B_1 is one of the most serious dietary deficiencies to which our populations are being subjected at the present time.' To this I would add that the inordinate use of refined sugar is one of the most serious addictions of the day. That the insufficient ingestion of Vitamin B_1 is an important and widespread cause of ill health--especially of gastro-intestinal ill health--is now recognized in America, where 'the bread-meat-potato-sugar' diet of many American people has recently been shown to be dangerously low in this important factor, unless it is supplemented with a sufficiency of milk, eggs, fruits, nuts and vegetables (Sure, 1933). And if in America, why not in this country also, where the average diet is of the same 'bread-meat-potato- sugar' sort? According to American observers the mal-effects of such a diet are chiefly to be observed in children who exhibit poor appetites, poor growth, nervousness, constipation and other digestive disorders: effects which I observed, and recorded, in monkeys eighteen years ago. For many years past I have advised European mothers in India to supple" ment the feeds of their infants with a watery extract of yeast in order to ensure an abundant supply of vitamin B', which cows' milk certainly does not provide in that country. A similar recommendation is now widely made in America, following the finding that not only cow's milk but the pooled breast milk of nursing women is relatively poor in vitamin B_1--poor because the women's own diets are poor in it. Many experiments have been made within the last few years on American children, the results of which show the good effect of the supplementary provision of vitamin B_1: better growth, better appetite, better assimilation of food and greater freedom from digestive disorders. Some clinicians in that country have come to the conclusion that a large proportion of the infantile mortality during the first year of life which is associated with gastro-intestinal disturbances may be due to vitamin B_1 deficiency consequent on the relative poverty of mother's milk and of cow's milk in this vitamin; a conclusion that has also been reached recently by certain observers in the Near East.

National Ill Health

What evidence is there of physical inefficiency in this country? and what that such as may exist is related in its origin to faulty nutrition? For answer to the first of these questions I must turn to certain authoritative publications. From the first of these--the Report of the Adjutant-General for the year 1934--I quote the following passage: 'What

was disconcerting to any citizen with a care for the good of his country was that over 52 per cent of the men who went to the recruiting office did not come up to the physical standard laid down. In the big industrial areas of the north the percentage of rejections rose to sixty-eight.' The opinion of a high military medical authority was that the chief cause of the men's rejection was malnutrition during childhood. These figures are in themselves sufficiently disconcerting, but more so perhaps when it seems likely that the men who did present themselves for recruitment were not so physically impaired as many who did not. And if so high a percentage of men falled to come up to the by no means exacting physical standard laid down by the Army authorities, how many of their womenkind were likely to be physically inefficient?

Another example, also of recent date, is still more disturbing: Not long ago the Pioneer Health Centre in Peckham carried out a survey of families of the artisan class, for whom the centre is intended. This survey revealed that 90 per cent of those over twenty-five years of age had some physical defect. From another source I glean the following statement: 'Among the insured population there were lost in 1933 a total of 29,000,000 weeks of work. To this staggering loss must be added the cost of replacement of labour and the expense entalled in the care of the sick during the period of incapacity. These figures represent a heavy burden upon the community which is largely unnecessary.' It is a burden however, that the community must continue to bear until it has learned that to be physically efficient the individuals comprising it must not only be taught to practice the principles of nutrition, but be provided with the means to practice them. It is to be noted in connection with this enormous amount of certified sickness that it was not of the killing kind--'the people were sick but not mortally sick.'* (**Spectator,* Oct. 19, 1934, p. 586.)

There is, too, the very high incidence of anaemia, due to deficiency of iron, in working-class women, to which attention has recently been drawn by Professor Davidson of Aberdeen. 'If', he says, 'the percentage of anaemic women found in Aberdeen is present in the industrial areas of the South (and we believe that anaemia may be even more serious there, since economic conditions are worse and the cost of living higher) then the loss of economic efficiency of the working-class mothers in this country must be enormous.'

The still very high incidence of tuberculosis, especially in adolescence, is another outstanding evidence of national ill health: 'During the last completed decade, 1921-30, there were, roughly speaking, forty-five thousand deaths of males and an equal number of females at ages 15-30. Amongst the males very nearly one-third of this mortality was due to tuberculosis while amongst the females the proportion was as high as one-half.'** It seems probable that a principal, if not a paramount, cause of this high incidence of, and mortality from, tuberculosis at this particular period of life is faulty food deficient in vitamin A, involving a low content of this vitamin in lung tissue and consequent susceptibility of the lung to infection. (**Report of the Chief Medical Officer of Health, 1933.)

As a final example of the prevalence of physical inefficiency, malnutrition in childhood may be cited. 'In his Annual Report for the year 1934, the Chief Medical Officer of the Board of Education repeats the emphasis of former reports on the necessity for satisfactory nutrition. During the routine medical examination 12 children per 1,000 were found to be malnourished and 14 per 1,000 undernourished' (I quote from the British Medical Journal). It may be taken as certain that a major proportion of this faulty nutrition was due to food of improper quality or to insufficient food or to both. Believing, as I do, that sickness is more often the result of malnutrition than malnutrition the result

of sickness, I venture to think that the evidences of malnutrition in schoolchildren are likely to be more widespread than these figures indicate. For it is not only that children suffering from malnutrition are underweight or under-grown; that there is a disproportion between their weight and height; that their posture is poor; that they are often round-shouldered and have protruding bellies, winged scapulae and lordosis; that they are of poor muscular development and easily fatigued; that they are irritable, haggard, anxious and, perhaps, mentally slow if not precocious; that they are wakeful, restless, and often troubled with unpleasant dreams; that they have headache and fleeting pains, sometimes in one part of the body, sometimes in another; although all these are signs of malnutrition. But there are others, indicating disturbances in structure or in function of organs or parts of the body: the circulation is poor; the skin is mottled or dry and hot, or moist, cold and clammy; there is usually anaemia; the digestive system is quite commonly unstable or disordered, constipation is frequent or may alternate with diarrhoea, the appetite is capricious--the desire for 'sweets' is often inordinate-- dental caries is the rule--and susceptibility to infection is very marked, especially infection of the upper respiratory passages. It is well enough to say that malnutrition may be brought about by faulty health habits or by physical defects, such as dental decay or gastro-intestinal disorder; it may. But these physical defects, this bad or capricious appetite, this constipation or digestive disturbance, this anaemia, this poor circulation, this faulty function of the skin--these are themselves consequences of faulty nutrition and, as a rule, it is this that gives rise to them, not they that give rise to the faulty nutrition. If we take this view of 'mal-nutrition' in schoolchildren--and for my own part I believe it to be the correct one--then it will be found that there are in this country not 12 per 1,000 who are suffering from it, but several times that number; nor will it be found to be confined exclusively to the poorer classes. Indeed, the widespread incidence of dental caries and of minor rickets is, in itself, sufficient evidence that this is so. There is one certain means of detecting dietetic malnutrition and that is by the assessment of the nutritive value of the diet that is actually being consumed; and in making this assessment attention must be paid as much to such essentials as calcium, phosphorus, iron and iodine as to vitamins, proteins and energy-bearing foods. If the diet does not contain in adequate amounts all elements and complexes needed for normal nutrition, then the user of it is suffering from, or will suffer from, malnutrition. It seems probable that a cause of malnutrition which may be overlooked is the non-provision of sufficient energy-bearing foods to meet the enormous expenditure of energy by growing children consequent of their bodily activities in sports and games.

The Death-rate and National Health

It is commonly stated that because the death-rate in this country is falling the national health is improving. Recently a writer in *The Listener* (20th November, 1935) voiced his dissent with this statement so pertinently that I am prompted to quote the major part of his letter, though recognizing that the falling death-rate is an achievement of which the public health services have every reason to be proud. This writer says, 'Again and again this fallacy appears in the Press. Why is it assumed that a falling death-rate connotes a higher standard of health? To save a man's life by drugs or surgery does not necessarily make a healthy man of him. The national health is the sum total of the healths of individuals; it can be nothing else. If the reasoning "low death-rate, therefore good

health" is sound, then if in an institution filled with incurables there is no death during the year, the death-rate becomes nil, and consequently the institution the healthiest place in England, though there is not a single healthy person in it.' The same writer goes on to say: 'What we should like to know is the number of semi-invalids carried by the nation; why all hospitals and nursing homes, etc., are full. . . . Why, under National Health Insurance, the increase between 1920 and 1930 of short-term (not exceeding six months) sickness was 109 per cent, of long-term (exceeding six months) 230 per cent; why the enormous decline in quality of eyes and teeth.' I am convinced that faulty nutrition due to the long-continued use of food of improper quality provides a no inconsiderable part of the answer to these questions.

Effects of Improved Diet

What evidence is there that by the provision of properly-constituted food, and of the hygienic amenities that should go with it, the physical condition of the people can be improved and disease prevented? There is, to begin with, the evidence provided by Dr. Cory Mann, at the instance of the Ministry of Health and the Medical Research Council, which demonstrated the unique value of milk as a food and the great improvement brought about in the physical condition of children by its adequate provision. Similar results have within recent years been obtained by investigators in Scotland. There is abundant evidence of the value of the free meals now issued, in increasing numbers, to poorer class schoolchildren, and of the value of the cheap milk made available by the Ministry of Agriculture. In a private communication which Miss Joan Fry made to me some time ago she spoke of the improvement in the health of the children of the unemployed allotment holders, under the beneficent scheme of the Society of Friends, consequent on their greater use of fresh vegetable foods. But perhaps the most valuable, because the most extensive and complete amongst investigations of the kind, is that recorded by Dr. G. E. Friend, Medical Officer of Christ's Hospital, Horsham. In his book, to which I have previously referred, he recounts the dietetic history of the school and the results of his physical and clinical surveys. These show that during the period for which reliable data have been collected there is a continuous upward trend both of weight and height of the boys consequent on improvements effected in the school dietary. Further, there is a definite decline in certain classes of illness, particularly of septic conditions, a diminution in the amount of dental caries, and a remarkable drop in the incidence of fractures and bone injuries. It cannot be doubted but that these results are in great part due to dietetic improvements, though improvement in hygienic conditions generally no doubt contributed its share to them. Nor have I any doubt in my own mind that had the dietetic improvements approached nearer to the provision of a perfectly-constituted diet, their beneficial effects would, with respect to the health of the boys, have been still more striking.

Chief Faults of British Diets

If now we turn to the Report of the Chief Medical Officer of Health for the year 1933, we find therein a certain uneasiness that all is not so well with the nutrition of the British people as it might be. It is affirmed that the evidences of malnutrition are not widespread. This is no doubt true of its grosser evidences. But is it true of the less obvious manifestations of faulty nutrition? If, as I maintain, the latter include many forms of

subnormal health, not all of which are scheduled in the Nomenclature of Disease, and of chronic ill health--many, in short, of the commoner degenerative ailments from which the people suffer: digestive, respiratory, osseous, arthritic, cardiac, haemic, glandular, inflammatory, etc.-- then are the evidences of malnutrition, indeed, widespread.

We may read in this Report that the food-essentials most likely to be deficient in the diets of the people of this country are proteins of high biological value, calcium, iron and vitamins A and D; and we may. perhaps, conclude from the use of the words 'most likely' that the diets of our people are not uncommonly deficient in one or more or al} of these essentials. If you are inclined to accept my own opinion, after what I have told you, there may be added to these likely deficiencies that of Vitamin B_1. I was assured recently by one who labours in the East End of London that such 'fresh' vegetable foods as utimately penetrate into that locality are usually many days old; and I am reminded, in this connection, of certain interesting observations made some time ago by one of my Indian assistants. He found that within seventy-two hours of gathering green vegetables from my well-tended kitchen garden in Coonoor, they lost the major part of their vitamin C content. I do not know whether the rapidity of this loss would be as great in England, where climatic conditions are so different; but it seems safe to assume that by the time their sparse supply of leafy vegetables reaches the dwellers in the East End of London the vitamin C content is considerably reduced. From which assumption I would be inclined to expect an inadequate intake of vitamin C by relatively large numbers of people in the slums of our great cities. But it is no longer necessary to make such assumptions, for in the 'Report on the Physiological Bases of Nutrition', recently submitted by a committee of experts to the Assembly of the League of Nations, it is stated that 'deficiencies in important nutrients are a common feature in modern diets, and these deficiencies usually occur in the protective foods (foods rich in minerals and vitamins) rather than in the energy-giving foods.' [The comment may, however, be made that the deficiencies do not occur in the protective foods themselves, but in modern diets because of the scanty use of the protective foods.]

We have, too, the authority of the Committee on Nutrition set up by the British Medical Association (1933) that 'a shortage of calcium, phosphorus and iron is not uncommon' in the diets of the people of this country. Let us, for a moment, refer back to my second lecture and see again what this not uncommon shortage means. It means, or may mean according to the degree of shortage, impairment of every vital function, stunting of growth, poor physique, poor bone formation, softening of bone, rickets (not necessarily of the florid type), tooth decay, crooked spines, impairment of muscular efficiency, including that of the gastrointestinal tract and heart, abnormal response of the nerves to stimuli, tetany, disturbance of menstruation and lactation, disturbance of the neutrality of the body and of the interchange of body fluids, ana emia and all its attendant consequences. This is what a shortage of calcium, phosphorus and iron means. And if with these we are to include a shortage of vitamins A and D, as the Report of the Chief Medical Officer of Health suggests we may, and of vitamins B and C--as there is good reason to believe we should--then to these consequences of mineral shortage there are to be added those of vitamin shortage, in themselves a formidable array and not the least important of which is lowered resistance to local infections. To those who do not know what the shortage of these essentials means, the mere statement that it commonly exists is not impressive. But to those who do--and you are now amongst that number, if you were

not so before--it must be obvious that faulty food is directly or indirectly responsible for a very large proportion of ill health to-day. If it be not, what then is its cause? You may search in vain for a more satisfying explanation of it.

Prevention of Disease by Diet

Concerning the matter of disease prevention and of the part which properly constituted food may play therein, I need give only three examples: the first provided by Miss Margaret McMillian in her book *The Nursery School*--which should be an obligatory text-book for every student of medicine; the second by the Papworth Village Settlement for sufferers from tuberculosis; and the third by the ante-natal work now being done in Dublin. Many others could, of course, be given. Hear what Miss McMillan had to say of the weakly and ill-conditioned children who came from the slums of Deptford to her nursery school; children, rickety and bronchitic; children with adenoids and dental caries; children with inflammatory states of eyes nose, ear and throat. After they have been nurtured and properly fed for three or four years they are, she tells us, almost all cured of any ailments they may have had, 'they are all straight and well grown, the average child is a well-made child, with clean skin, alert, sociable, eager for life and new experiences'. He does not need, she says, to seethe doctor or the dentist, and he has none of the minor ailments that affect the children of the slums. Surely this is an achievement of the highest order, an answer to the question how best to deal with 'the minor ailments that affect the children of the slums', and a cogent reason for the establishment throughout the length and breadth of the land of nursery schools of the McMillan type. It is a heartening sign of the times that the present Government intends actively to encourage their establishment.

And at the Papworth Village Settlement for the subjects of tuberculosis, what do we find? That in this village of 400 persons no child born there during the twenty years of its existence has, while a member of the community, contracted tuberculosis of the lungs, bones, joints, cerebral membranes, nor indeed any clinical form of the disease. Yet these children are the offspring of parents who suffer from tuberculosis and are in constant contact with them. How has this remarkable achievement been brought about? Sir Pendrill Varrier-Jones, to whose endeavours it is due, explains it as follows:

'1. Adequate food supply. Ignorance as to dietetic values is dispelled by advice at the clinic, by lectures and by the village nurse. Also by actual demonstration by food supplied from the Central Institution at small cost.

'2. Adequate food supply is possible because there is an adequate and prolonged parental income, maintained by means of assured employment.

'3. Freedom from anxiety as to loss of employment; therefore expenditure can be budgeted in advance.

'4. No risk of unemployment after breakdown; the income being maintained meanwhile *(a)* in the case of pensioners, by a pension, and *(b)* in the case of non-pensioners, by the Friendly Societies' contributions supplemented by the Welfare Fund.

'5. Proper housing, which allows medical advice to be put into immediate practice; such as through and thorough ventilation in living rooms; isolation of infected persons in bedrooms or verandas. That is to say, avoidance of mass dose.

'6. Public opinion, which makes it possible to live with windows open without being jeered at; to use sputum pots in the house, and pocket flasks out of doors, without being shunned or made conspicuous.

'To sum up--economic conditions determine the spread or otherwise of disease. To prevent disease it is necessary to create an environment rather than to give a dole where there is no opportunity for money to modify the condition of its recipient. The child's resistance to disease is maintained by *(a)* adequate nutrition, and *(b)* the absence of mass dose of infection.'

The ante-natal work which I was privileged to see when in Dublin a few years ago is another activity that is yielding remarkable results, because it is based on the sound foundation of improving the nutrition of expectant and nursing mothers. Three months before the expected birth of their babies the poorer class women come daily to certain centres, where they receive an excellent midday meal. They are cared for during their confinement and a fortnight thereafter they continue their visits to these dinner-centres for another three months. I am told that the infantile mortality amongst the children of these women is approximately one- third of that in women of the same class who cannot or do not avall themselves of these facilities or for whom there are, for lack of funds, not sufficient centres.

Maternal Mortality

There is much talk at the present time of the high rate of maternal mortality in this country, and much argument in regard to factors that may or may not be concerned in its causation. Amongst these faulty nutrition has come in for its share of blame. How far it is to blame we do not yet know, since the matter has never been thoroughly investigated. But it is a false argument which would maintain that because in some places maternal mortality is higher in well-to-do women than in women of the poorer classes, faulty nutrition can have nothing to do with it. For some women amongst the better classes have no idea how to feed themselves properly during or after pregnancy. There is abundant evidence, derived from experiments on animals, that the activity proper to the function of reproduction and to the health of the reproductive tract is influenced unfavourably by faulty nutrition. Of particular importance in this connection is insufficiency of vitamin A. It has recently been found (Mason) that levels of vitamin A-deficiency which are insufficient to produce xerophthalmia result in marked disturbances of the reproductive function in female rats. These include difficult labour, often associated with uterine bleeding and infection. Observations such as these may have an important bearing on maternal mortality in human beings; for of this we may be certain, that unless the diet of the expectant mother conforms in every detall to the physiological requirements of pregnancy her chance of surviving the ordeal of childbirth will be lessened. In my second lecture I mentioned, under the various food-essentials there discussed, the amounts of some of them that are needed during pregnancy. These may be enumerated again: a well-balanced diet containing 70 grammes of protein, of which one-third must be derived from animal sources; an abundance of all vitamins, including vitamin D, which, however, should be provided in the form of cod liver oil so as to avoid the risk of overdosage and as an additional source of iodine; 2 grammes of calcium; 1.6 grammes of phosphorus; 0.3 gramme of magnesium; and 20 milligrammes of iron. Personally, I believe that the best diet for expectant mothers is one made up of whole cereal grains, milk, milk products and eggs, with fresh green vegetable foods and fruit in abundance.

Mention has already been made of the part which antecedent rickets and osteomalacia may play in increasing the risks of childbirth by causing alterations in shape of the female

pelvis.

'Building of an A1 Nation'

If I have convinced you of the fundamental importance of food in relation to public health, it will have become obvious that one of the most urgent problems of our time is how to ensure that each member of the community shall receive a diet that will satisfy his or her physiological needs. It is clear that to achieve this much-to-be-desired end many barriers--poverty, unemployment, apathy, ignorance, prejudice, habit--must be surmounted, and many interests--agricultural, industrial and economic--readjusted. To do so is, in the main, a primary function of Government. For, as Carlyle expresses it: 'Wherever the health of the citizens is concerned . . . all governments that are not chimerical make haste to interfere.' During the recent election campaign one read of plans for 'the building of an A1 nation'; ante-natal, child-welfare and maternity services were to be improved and extended; nursery schools for children under school age were to be actively encouraged; increased facilities for treatment, particularly dental treatment, were to be provided, orthopaedic centres and open-air schools were to be formed; the medical insurance scheme was to be extended to include persons of younger age; physical education was to be undertaken. All these are well enough--and laudable; they are, indeed, essential parts of a properly organized policy of health. But without measures that will ensure the better feeding of the people they cannot, like a diet inadequate in vitamins though complete in other regards, achieve the end in view-- 'the building of an Al nation'. But while the main burden of achieving this end must rest on Government--and a heavy burden it is--there is much that individuals can do for themselves, much that the medical profession and the professions allied to it can do, much that the teaching profession can do, much that all people of education can do. For they can make it their business thoroughly to acquaint themselves with the principles of nutrition, to practice these principles and to inculcate them in others. These principles are not difficult of comprehension, their practice is simple, and the benefits to be derived from their practice are sure. Fifteen years ago, in a book from which I have ventured to quote already, I wrote as follows: 'With increasing knowledge of nutritional problems, it has become apparent that our dietetic habits need remodelling, and that education of the people as to what to eat and why they eat it is urgently necessary. It is clear that green vegetables, milk and eggs should form a far higher proportion of the food of the nation than is now customary. So far from curtalling the beneficent scheme whereby portions of land were made avallable during the war for cultivation by allotment holders, this scheme should be extended and facilities given to allotment holders for the keeping of fowls. Municipalities and other public bodies should concentrate on the provision of an abundance of milk, eggs and vegetables, for there is no measure that could be devised for improving the health and well-being of the people at the present time that surpasses this either in excellence or in urgency.' To-day, fifteen years later, there is little I can add to this exhortation. Its truth is now generally admitted. It is, indeed, the essence of the 'Report on the Physiological Bases of Nutrition' submitted by a special committee two months ago to the Assembly of the League of Nations. It emphasizes two needs, as urgent to-day as when these words were written: the need for education in the principles of nutrition and the need for the employment of many of our 'unemployed' in the production of more milk, more eggs and more vegetable foods. Concerning this matter of the employment of

the unemployed, I need only point to the splendid efforts of the Society of Friends; efforts which provided assistance for 120,000 unemployed men in 1934, and enabled them to produce fresh foods to the value of £600,000. I understand that the sole barrier to its further extension is want of funds. In a letter to The Times, about ten months ago, I appealed, in this connection, for the more prudent expenditure of public funds. I repeat the appeal here: 'Year by year we import vast quantities of vegetables all or most of which could be produced in our own country and by our own people. Long before these vegetables reach consumers of the poorer classes they have lost, especially those of the green leafy kinds, much of their health-promoting properties. . . . Surely it is prudent to provide our people with these important foodstuffs in a state as fresh as possible. Their production should therefore be greatly extended and their speedy distribution ensured.

'It is schemes such as that of the Society of Friends for the provision of allotments for the unemployed and for settlement on the land that deserve generous financial support rather than the expenditure of vast sums on the production of a food-material (sugar) whose consumption by the nation as a whole is vastly in excess of the nation's need for it. The need of our people for fresh vegetable foods, procurable at a cheap rate, is great--as great as their need for clean, cheap milk. Thousands of our people stand idle in the market place who would be well employed in the production and distribution of these health-giving foods. It should not be beyond the organizing capacity of a nation that produced a vast citizen army to meet the curse of war to organize a citizen army to meet, by the adequate production and distribution of fresh vegetable foods, dairy produce and eggs, the curse of preventable disease'. To this last phrase I can add nothing except to say that it envisages what England needs, and needs most urgently; for in this way there lies a solution of some of the problems of agriculture, unemployment, and improvement of national health.

It may, perhaps, be objected that, as it is, we produce more milk than our people can, under present conditions, buy. But the greater consumption of milk is now a national necessity and means must be found to ensure it. Coming from a country where, perforce, all milk must be sterilized by heating, the objections to its sterilization do not appear to me to be so great as some appear to think. It is true that this treatment does deprive it of some of its nutritive quality, but of little that cannot be made good by the adequate use of fresh vegetable foods; while even in its sterilized state, it remains one of the best and cheapest of all foodstuffs. Would it not be possible to sterilize milk in large centres of its production and distribute it in suitably sized sealed tins? Means have been found for the safe distribution of inflammable petrol--a cheaper fluid than milk--can none be found more efficient than the bottle for the house-to-house distribution of contaminable milk? At present the housewife in the slums of our great cities has often no place suitable in which to keep a reasonable supply of milk; the sealed tin might help to solve her difficulty, and a little knowledge help her to keep her supply untainted. However this may be, sterilized milk is vastly better than no milk, or than too little milk however pure it be. This also must be said: the provision of fresh vegetables is complemental to the provision of milk--the one is as much a national necessity as the other.

A notable attempt has recently been made in Bombay to improve the diet of the common people, and, after much trial in schoolchildren, a balanced and very inexpensive diet has been evolved that appears to satisfy physiological needs. This has been achieved by the inclusion in it of whole cereal grains, dried skim milk, soya bean, ground-nut,

pulses and green-leaf vegetables. So long as we in England insist on including in our dietaries the more expensive, though not necessarily the most nutritious foodstuffs, so long will a balanced diet be beyond the reach of many whose means are limited. In a recent authoritative report it is stated that meat is among the 'protective foods'. It is probably so included because it is a rich source of 'good protein' and of vitamin B_2. But it is poor in certain other essentials, and is, indeed, one of the foodstuffs whose defects are made good by milk and green-leaf vegetables, to which McCollum originally applied the term 'protective'. As recently as 1934 he writes: 'There are available only two types of protective foods, or foods which are so constituted as to make good the defects of a white bread, meat, sugar and potato type of diet. These are milk and leafy vegetables.' It is, to my mind, inadvisable to include in the category of 'protective foods' a wide range of expensive foodstuffs, some of which may be beyond the reach of many of our people. By naming meat 'protective', the impression is created that health depends on its inclusion in the diet, which it does not. Far better is it to encourage the use of inexpensive but none the less nutritious foodstuffs (milk, cheese, herrings, wholemeal bread, vegetables, etc.), from which satisfying and well-balanced meals can readily be made at a relatively low cost. It is here that education is called for: education not only in food-values but in the correct and inexpensive selection and combination of foodstuffs.

Education

In this matter of education in the principles of nutrition two of the great professions--the medical and the scholastic--are in a position greatly to aid the endeavours of Government in 'the building of an Al nation'. In regard to my own profession I may repeat what I wrote fifteen years ago: 'It is for us so to instruct ourselves that we may . . . use our newer knowledge to the end that customs and prejudices may be broken and a more adequate dietary secured for those under our care.' 'There can be no doubt', said the *British Medical Journal,* in a leading article last year, 'but that this newer knowledge of nutrition has placed in the hands of our profession a potent weapon against disease-- a potent instrument in the promotion of physical efficiency and wellbeing. It behoves us, therefore, to become proficient in this knowledge, to apply it in the daily course of our work, and to spread it by every means in our power.' A special responsibility attaches to our medical schools in this respect. 'At present medical students during the early years of their course are given a few lectures and demonstrations dealing with the physiology of nutrition, and perhaps carry out a little laboratory work in this field; the subject is presented as a chapter of physiology, and not as an integral part of preventive medicine.' The authors of the League of Nations Report*, (*Nutrition and Public Health, 1935.) from which we here quote, are 'far from suggesting that yet another speciality should be added to the already congested medical curriculum'. But surely a subject that is 'an integral part of preventive medicine' must in the future be given a place in the medical curriculum commensurate with its importance. In its teaching we must be content with no half-measures. The student must have the opportunity to see with his own eyes the havoc that is wrought in the various organs and tissues of animals subjected to faulty nutrition of various kinds and degrees. Only when the medical profession is itself so instructed, can it play its proper part in the instruction of the public.

The next most important direction in which educational effort is required is in the teaching of the elements of nutrition to schoolchildren: 'We spend millions', said Lord

Bledisloe in a letter to *The Times*, (6th November, 1935.) 'on feeding the minds of the youth of the nation. Is it not time that we spent a little (as an essential part of all school curricula) on showing those young people how rationally and sensibly to feed their bodies and those of their prospective progeny?' Here he goes to the root of the matter, for it is only by the instruction of youth that the faulty food habits of the people can ultimately be altered and the desire created for those things that be good from the nutritional point of view. This desire will lead to the demand for them, may be translated into the greater production of them and, perhaps, lead also to the return of many more people to the land--a thing greatly to be desired. But to teach the children the teachers must themselves be taught, and this requires the adequate provision in all training colleges for prospective entrants into the scholastic profession of facilities for the acquisition of a thorough knowledge of the subject. These facilities do not, so far as I can learn, now exist, or if existing they are not adequate. Their provision is an urgent matter. It 'should set the Board of Education thinking more deeply on a question which vitally affects our national physique'.** (***Observer*, 17th November, 1935.)

We have the assurance of Dr. Mary Swartz Rose, Professor of Nutrition, Teachers' College, Columbia University, than whom there is no greater authority on the teaching of nutrition to boys and girls, that it is a subject to which they take readily when it is properly taught. Her own book is a model of how such instruction should be given. An essential part of this instruction, as advocated by Professor Rose, is to give children the actual experience of feeding animals (rats, guinea-pigs) on different diets and to let them see for themselves the influence of food on health and growth.

There are many other directions in which organized effort is needed in regard to education in nutrition: the employment of public health nutrition workers and of 'nutritionists' and 'dieticians', as is now so largely done in America; the teaching of nutrition in schools of domestic science; education work among rural populations; publications and propaganda. These matters are all dealt with at length in a recent publication by the health organization of the League of Nations.*** (****Nutrition and Public Health*, IV, February, 1935.) But behind all such effort there is the dark cloud of economic conditions that make it difficult, if not impossible, for large numbers of our people to procure diets that will satisfy their physiological needs. Happily there are signs that this cloud is lifting, and there is no lack of evidence both of desire and of effort to ensure a better way of life for the less fortunate amongst us. Until this cloud is dispelled the distribution of relief in kind might well be resorted to. Collective feeding has much to recommend it, both for workers and for unemployed.

In dealing with a subject so vast as nutrition, the lecturer, perforce, confines himself to certain aspects of it--usually those that have come within his own experience. For my own part, my interests have lain in the direction of learning what I could of the relation of faulty food to nutrition and of both to health and disease; and out of this desire to learn there has come the desire to spread such knowledge of the subject as we already possess. It has been my endeavour, during these lectures, to convey this knowledge to you, in the hope that with understanding there may come belief. Belief that the continued use of properly-constituted food, from the earliest period of development onwards throughout life, is the surest means we have of acquiring and maintaining that condition of body--good health--which is 'the vital principle of bliss':

This Life-joy, like the breath-kiss of the all-ambient air
unnoticed til the lack of it bring pain and death,
is coefficient with the untramlel'd energy
of nativ faculty, and the autometric scale
of all functions and motions, . . .
it is the lordly heraldry of the banner'd flower,
in brutes the vaunt of vigour and the pose of pride,
their wild impersonation of majesty; and in man
the grace and ease of health alike in body and mind,
that right congruity of his parts, for lack whereof
*his sanity is disabled, main'd and compromised.**
ROBERT BRIDGE

**From The Testament of Beauty*, by Robert Bridges (Clarendon Press, Oxford).