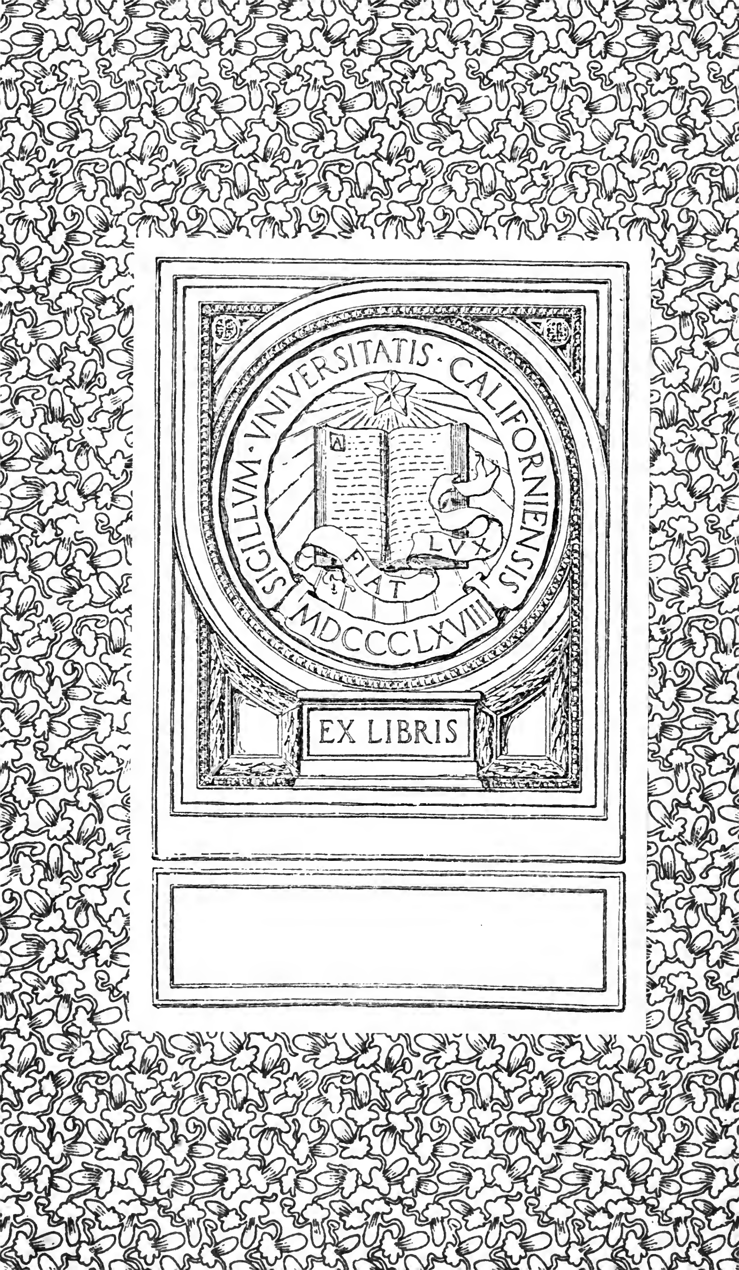

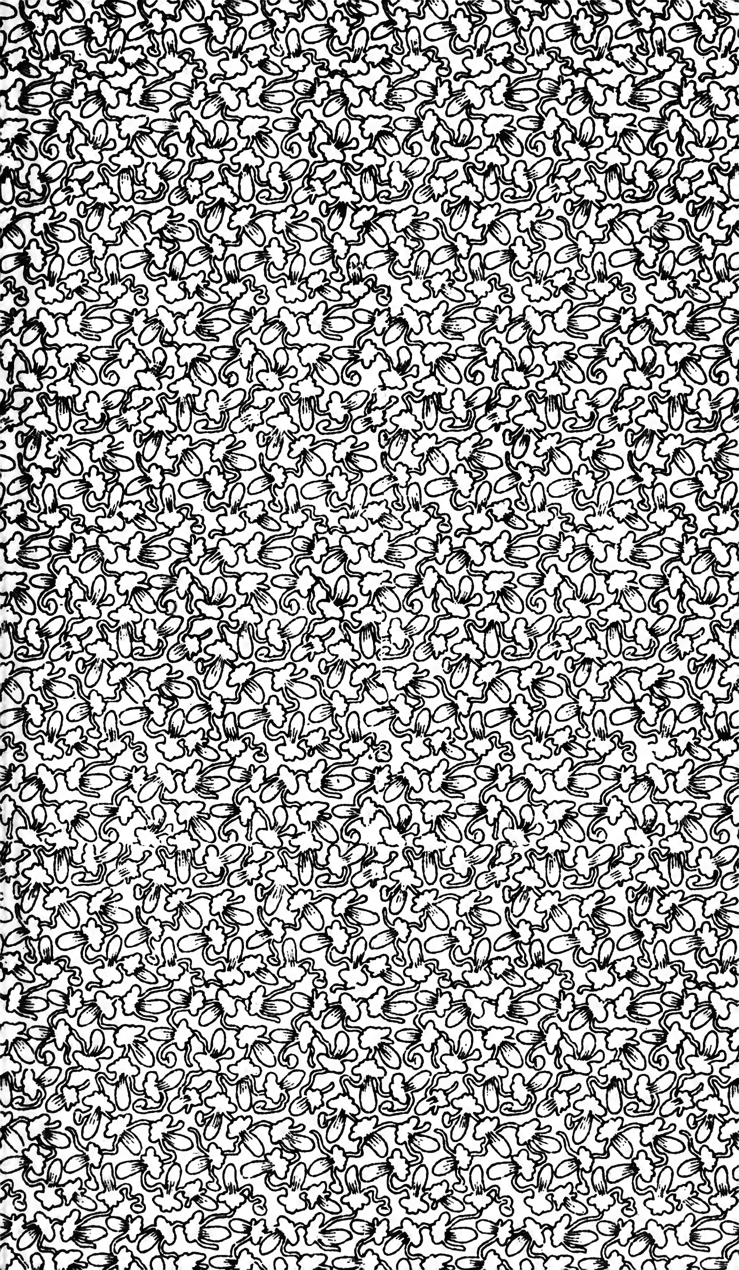

THE PHYSIOLOGY OF FOOD AND ECONOMY IN DIET

BY

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PREFATORY NOTE

This little manual has arisen from a course of public lectures given at University College, London, in October and November, 1916. It has been thought that a useful purpose might be served at the present time by making these lectures more generally accessible. Although no previous knowledge of physiology is assumed, references are inserted to sources of more detailed information on certain questions for those readers who may desire to enter more deeply into these questions. Occasionally, points of interest are indicated which, though unessential to the main argument, will be found to appeal to the reader possessing the necessary scientific preparation.

I would especially acknowledge my indebtedness to the booklet by Wood and Hopkins, *Food Economy in War-Time.*

It may be pointed out that the problems involved are not only of importance in war-time, but also in times of peace, since waste should always be avoided, as far as possible.

W. M. B.

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THE PHYSIOLOGY OF FOOD AND ECONOMY IN DIET

CHAPTER I

THE PROBLEM AS A WHOLE

ALTHOUGH many physiological problems have been brought into prominence by the War, most of these concern people as a whole only indirectly. That of Food, however, is of immediate interest to us all. Leaving on one side that aspect of the matter which may be regarded as, in a sense, æsthetic, associated with the gratification of the sense of taste, it may be taken for granted that every one is sincerely desirous of avoiding unnecessary consumption of food, so far as it can be done wisely and without diminution of value of the individual as a member of the community.

We have to inquire, therefore, into the uses of food, into the amount necessary to fulfil these uses, into the necessary constituents of an adequate diet, and into the ways in which these constituents can be supplied most economically. Some subsidiary questions will need brief discussion, such as the part played by digestion and the use of alcohol. It is, indeed, remarkable how widespread is the impression that butchers' meat has some specially valuable properties ; and that sugar, amongst other things, should not be regarded as a food in the true sense of the word. Again, there are some people who appear to be under the belief that the more food eaten the better, so long as it is digested, We hear of a "fine healthy appetite," when the person spoken of is probably really consuming much more than he needs.

We shall see later that there is no probability of any actual deficiency in the food supply as a whole, although there is undoubtedly already some scarcity in particular articles of diet, and prices have risen all round. We want to know how far we can avoid costly articles or replace them by cheaper ones, without any disadvantage. It is scarcely necessary to remark that saving in unnecessary expense enables more money to be devoted to national needs, as by purchase of War Loan and so on. Here we may note that the problem is not merely a physiological one, it is a complex one of economics also. I call attention to this point, although it is outside the scope of the present inquiry. If, for example, a great demand were to arise for some particular article of food on account of its cheapness, this demand in itself would produce a rise in price. It seems that the best course to take to avoid economical disturbance is that indicated by Wood and Hopkins (1916, p. 3; see List of Literature at the end of this book). This is, that articles whose price is either falling, or only slowly rising, should be selected rather than those whose price is rising quickly. This of course implies an observation of the market prices from day to day. We may hope for guidance in this respect from the Government Departments.

It may be well, before we proceed further, to state the general conclusion to which we shall arrive. This is, that any kind of diet which is at all likely to be chosen in the British Isles will contain all that is necessary, provided that it be taken in the right amount. Even potatoes alone, under favourable conditions, can be made to suffice, as we shall see later. It is not in the least probable that any reasonable person here would attempt to live only on polished rice, still less on a pure chemical product such as cane-sugar or olive oil.

In the succeeding pages, I attempt to give, in as simple and elementary a manner as possible, the essential facts of the science of nutrition. At the same time, I do not feel compelled to avoid occasional reference to somewhat more difficult aspects of the subject, but only where they may be of interest to readers already in possession of some physiological knowledge and where they may be omitted by others without loss of what is of immediate practical importance. It may happen, of course, that readers of the latter kind will be deprived of the proof of some statements which rest on the more difficult parts of physiological investigation. I must ask them to take such statements on trust.

We will proceed to discuss, in order, the reasons why food must be taken, the essential components of food, the quantity of these required, and finally some practical suggestions following from the physiological facts brought forward.

CHAPTER II

THE USES OF FOOD

1. *Growth.* — When a living being is increasing in size, it is perfectly obvious that materials must be supplied for the purpose, and that the supply must contain in some form the actual chemical constituents of the new tissues formed.

2. *Maintenance.*—Even in the adult, the various parts of the body undergo waste by wear and tear, just as any other machine does. This loss must be replaced, and again material containing the chemical elements of the substance lost must be supplied. When we say this, it is not to be understood that the same actual chemical compounds as those contained in the body must be given in the food. But, since chemical elements, except under very special conditions, cannot be

changed into other elements, food which contains some compounds of the elements found in the body must be taken. For example, new growth contains compounds of nitrogen; therefore, food containing nitrogen must be available.

These two functions of food are very closely related, although not necessarily identical. Under certain circumstances, moreover, as in the training of an athlete, new muscular substance is produced. So that, even in the adult, material for actual growth is sometimes required.

3. *Work.*—But the greater part of the food, both in the young and in the adult, is needed for a different purpose, a fact which is frequently apt to be overlooked by those who are unfamiliar with scientific studies. While the addition of new substance and the replacement of that lost are sufficiently plain to most people as requiring food, the necessary consumption for the purpose to which I am now referring is somewhat intangible.

One of the most characteristic of the

properties of living beings is the perpetual change shown by them: they are always doing something, as one may say. Now, universal experience teaches us that such activity means doing work, and that this implies the loss of something by the worker. The capacity of doing work is called *energy*, by physical science. An extremely important fact, on which the whole of science is based, is that energy can be measured exactly. And the loss of energy in doing work is precisely equivalent to the work done. Having measured by an appropriate method a particular amount of energy, we know that we can obtain from it just so much work and no more. As a matter of course, then, if work is to be done by our muscles, they must be supplied with a source of energy. This is done by what we may call, with justification, combustible substances in food. The fact that work can be obtained from the burning of coal under a steam-boiler is familiar to every one. There are numbers of similar materials which burn in air, and one of the most instructive experiments which can be performed is the very simple one of showing that the products of the combustion of sugar in air and those found in the air which we expel from the lungs are identical. These latter arise from the burning of sugar and other foods in our bodies for the purpose of affording energy to perform work. An important practical fact—which follows naturally from what has just been said—is, that the greater the quantity of work done the more fuel is required. Probably one of the most significant results of modern physiological research, is that there is an exact balance between the energy taken in and that given out in the form of work of various forms. From this, again, it is plain that energy may exist in different forms ; the chemical energy of the food is transformed partly into that of muscular contraction, partly into heat, and so on. But none is lost and none is ever created. Some readers will doubtless recognize this statement as what is known as the first law of energetics, that of the *conservation of energy*, and it is one of the greatest modern physiological achievements to have shown that it applies no less to man than to inanimate nature.

We see that food is required for two main purposes: (1) for growth or repair of bodily substance; (2) to afford energy. Since a great variety of different materials are capable of being burnt up for this latter purpose, although they may not contain what is wanted for growth, it follows that the requirements are different for the two purposes. While the food stuffs needed for growth and maintenance do, as a matter of fact, contain combustibile constituents, and thus give energy, there are other food stuffs, which are equally valuable as producers of energy, but insufficient for growth.

The general facts may be better understood by comparison with a *petrol motor.* Such a machine in process of construction requires certain materials—steel, iron, brass, insulating material and so on—some of which cannot be replaced by others. When finished, and set to work, a supply of these materials is no longer necessary, but a combustible fuel is used as food for the engine. This fuel is burned in the cylinder, and the energy afforded can be made use of for various purposes. Notice that the fuel does not become part of the motor, but that its energy is made available by means of the mechanism. Now, in process of time, certain parts, such as the piston rings and valves, wear out and must be replaced by new ones, whereas there are other parts, such as the fly-wheel and the general framework, which last for the duration of the life of the engine, except for accidents. There are also other suggestive points of resemblance to the animal machine. Attention will be directed to these later.

Proceeding now to further details, we may first consider the nature of the food necessary for growth and maintenance.

Examining the *constituents of the animal body*, we find that they consist of numerous compounds of carbon with nitrogen, hydrogen and oxygen. Some of these contain also sulphur and phosphorus. In addition to these, there is a large amount of water and a small amount of some inorganic salts, chiefly of sodium, potassium and calcium.

As regards *water*, this does not afford energy, since it is already completely burnt or oxidized. But it may be looked upon as a kind of food, in so far as it is necessary for the proper working of the animal machine, and may be compared to the lubricating oil used for the moving parts of the petrol motor. As water is continually being lost from the lungs and kidneys, it must be replaced. In civilized and habitable places there is, or ought to be, a copious supply of good water, a matter which is by no means the least important one to ensure.

As regards *salts*, similar remarks may be made. The machine will not work without them; but, except under special conditions, they are taken with other forms of food, being contained therein. The only salt commonly consumed as such is sodium chloride, ordinary table salt. Further remarks in connection with water or salts will not be required.

What about the *carbon compounds* which form the greater part of our bodies? As is well known, the large body of doctrine known as organic chemistry is concerned with these, and the name is due to the fact that the first compounds of this kind were obtained from plants or animals. We may ask why the compounds of carbon should have this special place of honour. It is interesting to consider for a moment what are the peculiarities of carbon that have caused it to be the basis of the evolution of life. In the first place, carbon is quadrivalent, as the chemists call it; that is, it can combine with four other elements or groups. Moreover, its atoms possess in a special degree, unknown in the case of other elements, the power of combining with each other, so that long chains or rings are formed. Compounds containing as many as two hundred or more atoms are known to exist. Another important fact about carbon is its position with respect to other elements with which it may combine. The chemical elements can be arranged in a series, such that those at opposite ends have the greatest "affinity" for each other. In other words, they combine together with the setting free of large amounts of energy. Oxygen and hydrogen, for example, are a long way apart in this arrangement, and they combine with great violence. Now, carbon is somewhere about the middle, so that it can combine with either hydrogen or with oxygen. In the latter case, we have the universal product of combustion of carbon compounds as it takes place in living organisms, as well as in the non-living world. This is carbon dioxide or carbonic acid, as it used to be called, since it forms an acid when dissolved in water. In this process of combustion, energy is given off. On the other hand, carbon can be made to combine with hydrogen, giving rise to the well-known paraffin oils and similar hydrocarbons. But, in this case, energy must be supplied from outside. These compounds of carbon and hydrogen, when burnt, give out large quantities of energy, as is familiar to all, at all events in one of its forms, that of heat. We see thus that carbon serves as an admirable means for the transference of energy in vital processes.

The carbon compounds in the form in

which they leave the animal body, after being made use of, are, nearly all of them, completely burnt up, so that they contain no more available energy, or merely a negligible quantity. It is clear, therefore, that some means must exist for converting them back again into food-stuffs containing energy. A description of this means is beyond the scope of this book; in brief, it may be stated that it is provided by the green plant, with the aid of energy derived from the rays of the sun. This energy is stored up in the form of compounds from which the oxygen has been partially removed, which then serve as sources of food to give energy to the animal. Thus, our energy is derived from the sun. Further details may be found in my *General Physiology* (1915), pp. 558–569.

Animals are dependent for their food either on plants or on other animals, that is, ultimately on plants in all cases.

Since all the constituent parts of the body structures contain nitrogen, food must be supplied containing this element. The simplest chemical compounds of this kind which can be used by the higher animals are those known as *amino-acids*. One of these is formed from acetic acid, familiar in vinegar, by the combination with it of a derivative of ammonia, which contains nitrogen. There are a large number of different amino-acids, and together these have been found capable of serving as nitrogen food, without the addition of other nitrogen compounds. But, as a regular diet, they would be impossible on account of the difficulty and cost of preparing them, apart from objection on the ground of taste. Accordingly, what we actually use are the various compounds, consisting of amino-acids united together, which are found in the tissues of plants and animals. These compounds are known as "proteins," a name which will be frequently used in succeeding pages, and has even become familiar from the pages of the daily press. Certain of these proteins contain sulphur and phosphorus, so that the supply of these elements is provided for. The word "proteid" is now obsolete.

In actual practice, very few foodstuffs are of such a nature that they can be used by the cells of the body without being split up into simpler substances. Proteins, for example, must be converted into amino-acids, and starch into sugar. This is the function of the process known as *digestion*, to which our attention will be devoted presently.

An important point with regard to the materials required for growth is that different proteins are composed of different mixtures of amino-acids, such that one or more may be absent from a particular protein. Such a protein, therefore, would only be an adequate source of nitrogen if the amino-acid wanting could be formed in the body from those which are actually present in the food itself. But there are some amino-acids which cannot be so formed. A protein which does not contain them is accordingly not, of itself alone, adequate as a source of nitrogen food. Such a contingency is not likely to happen in the British Isles, but must not be forgotten where there is a possibility of a limited variety in protein diet.

It may be remembered that, in our illustration of the petrol motor, it was pointed out that there are parts which do not require renewal on account of wear and tear. It is not unexpected to find that, after the working machinery of the body has been constructed, certain parts of it also do not appear to suffer loss in this way. Hence, a particular constituent of food may be necessary for growth, but not for maintenance. Some experiments made in the United States seem to show that this is actually the case.

The important fact, however, for our present purpose, is that the products of wear and tear contain nitrogen, both in the adult and in the growing child.

Turning next to the second function of food, the supply of energy, there are a few more facts needed in order to make further discussion intelligible.

While there are many forms of energy—mechanical motion, heat, electricity and so on—these can be converted into one another. Indeed, practically all the energy which we make use of is derived from the chemical energy of the food taken. This food, when burnt by the oxygen taken in by respiration, sets free energy which is converted into the various forms required. As Clark Maxwell has put it, the transactions of the material universe are carried on by a system of debit and credit in which energy changes hands, as it were. Now, it is just in this transfer of energy that the phenomena which particularly strike us as characteristic of living beings are manifested. It is while in the act of transference that it is especially capable of being made use of. Just as in commercial transactions money can be most readily appropriated when passing from one form to another. From another point of view, while life lasts there cannot be a real state of equilibrium. Life means activity, and activity means transfer of energy.

When it was stated above that all forms of energy can be changed into one another, it must not be understood that the whole of any one form can be changed into the equivalent value in any other form. While this is true for all forms of energy with the exception of heat, in this latter case the whole cannot be converted into another form of energy. This fact impresses upon us the consequence that, when once energy has become heat, a part of it is lost for other useful purposes. It is no longer "free" energy, and is sometimes said to be "degraded" to heat. Kelvin called attention to this fact under the name of the "dissipation of energy," and to many readers it will be recognised as involved in the *second law of energetics*, or, as it is often called, Thermodynamics. The name Thermodynamics as applied to the laws of energy, arises from the circumstance that these laws have been mostly made out from investigations on heat energy.

The special position of heat as regards convertibility may possibly be due to the fact that under ordinary conditions we can obtain an absence, or zero value, of all other forms of energy, but that the zero of heat is at a temperature 273°C. below the freezing point of water.

The reader will probably ask what this discussion is meant to lead to. Its immediate object is to explain the name, *calorie*, a unit in which the energy value of food is now universally expressed. The calorie is that quantity of heat energy required to raise the temperature of one kilogram of water by one degree centigrade, or, more precisely, from a temperature of 15° to that of 16°. Now, while every one is quite familiar with differences of temperature, the conception of quantities of heat is not quite so easily grasped. Perhaps the distinction may be realized by reference to the homely illustration of a hot-water bottle used to warm the bed. It will be granted at once that if only a table-spoonful of boiling water is put into the bottle, very little benefit will result, whereas if it is filled with water, *at the same temperature* as before, the bed may be comfortably warmed. Thus, the heat required to raise the temperature of two kilograms of water by one degree is double that required for one kilogram, and the amount of heat energy contained in the former is twice that in the latter.

The reason why the energy value of food is expressed in heat units is, that this is the most convenient practical method of determining the total energy that can be obtained from the food. It is done by burning a known weight of the foodstuff in oxygen and measuring the amount of heat produced by the combustion. The heat is caused to raise the temperature of a known amount of water.

But it is very important to remember that the whole of the energy of food is not necessarily converted directly into heat in the body. It is used more economically, as the second law of energetics tells us, by direct conversion into other forms of energy. In the contraction of muscle, for example, the potential energy present before activity is converted into that of the pull exerted, without any loss as heat. It is only in the subsequent recovery process that a loss occurs. Of course the production of heat is not altogether a loss, at all events when the external temperature is lower than that of the body. Heat is necessary to keep up the normal temperature. But, nevertheless, the distinction sometimes made between "flesh-forming" food, by which protein is meant, and "heat-forming" food is misleading. It suggests that protein is the special food for muscle, that non-nitrogenous kinds of food form heat only, with the exclusion of energy of other kinds, and that protein itself does not form heat. None of these statements is correct.

Oxygen.—No energy can be obtained from food unless it is burnt by combustion with oxygen. Oxygen is consumed in all active organs of the body, as shown by the dark colour of the blood in the veins leaving them. As can easily be tested by any one, blood becomes bright red when shaken with oxygen or air, dark crimson when the oxygen is removed. The bluish colour of the veins is due to reflected light. Since oxygen is universally present in the atmosphere, it is not usually regarded as a food; but it is really the most important of all foods.

In point of fact, however, it is not easy to explain the obviously beneficial effects of *fresh air*. There is no actual deficiency of oxygen in many rooms which seem "stuffy," so that the cause of the unpleasant results of remaining in such places must lie in some other factor. A partial explanation may be, as Leonard Hill contends, that the effect is due to the absence of currents of air and the stimulation of the skin produced by them. It would thus be a result of failure of stimulation of the nervous system. The general experience of more refreshing sleep obtained when the bedroom window is open tends to support the view of the importance of the effect on peripheral sense-organs. The benefit of a *cold bath* is probably of a similar nature, as also that of *exercise*, to a certain degree. Further remarks on the question of exercise will be found below.

CHAPTER III

THE THREE CLASSES OF FOODSTUFFS

After this somewhat lengthy, but necessary, physiological introduction, we are in a position to consider with profit the materials actually consumed for food and to deduce practical conclusions as to their use and value. Readers who desire more information on the physiology of nutrition may consult the textbook by Lusk (1909), or those sections of the works of Starling (1915), or of the present author (1915), which deal with the subject. The titles of these books are given in the list at the end of this manual.

In order to produce new growth or to replace tissue lost, nitrogen, as well as carbon, hydrogen and oxygen, is required, because these elements are contained in the new tissue. Proteins, therefore, in some form, are a necessary component of an adequate diet. Other articles of diet do not contain available nitrogen. Protein, moreover, is able, if taken in sufficient amount, to afford all the energy required. But, in order to do this, a large excess of the nitrogenous component of protein must be dealt with by the body; and, since this nitrogenous part affords no appreciable energy and is greatly in excess of that needed for building or repairing purposes, it is merely wasted. The energy to be obtained from protein is practically the same as that of an equal weight of sugar ; but since, as we shall see, it is the most costly of all food materials, to use it for the supply of energy only would be very wasteful, provided that other materials are capable of serving the purpose. It is as if we were to use for fuel in a petrol motor a petroleum spirit containing copper in fine powder. The copper would merely drain away from the cylinder in the waste lubricating oil, just as the excess nitrogen of protein leaves our bodies in the form of urea in the urine, without having fulfilled any useful purpose in the activities of the organism. The energy value of proteins is, in fact, only a trifle greater than that of their hydrocarbon part alone.

Now it is familiar to every one that there are many substances in the world which give out energy in the form of heat when they are burnt. Such are charcoal, metallic magnesium, paraffin candles, as well as butter or sugar. None of these contains nitrogen. As regards the materials typified by the first three mentioned, the higher animals possess no agents in the alimentary canal capable of rendering them soluble in such a way as to be able to gain admission to the blood. Even if they did so, the oxidizing mechanisms of the body would be unable to deal with them, although it appears that certain micro-organisms can utilize paraffin oil. Cotton fibre also is useless for man's food, although herbivorous animals make use of it ; it is said that sheep grow fat on blotting paper. The second things mentioned, typified by butter and sugar, on the other hand, can be "digested," as we call the process of acting upon them so as to make them able to be oxidized. They are then burnt in such a way as to render their energy available in some form or other.

Butter and sugar represent two classes of food stuffs, the *fats* and the *carbohydrates*, both of which are consumed for the purpose of affording energy. The energy requirement of the adult being at least nine times as great, as regards weight of the food taken, as that of the nitrogen requirement, the advantage of using cheaper forms than that of protein is obvious.

A word or two may be said with respect to the chemical nature of fats and carbohydrates. *Fats* are compounds of glycerin with acids containing a large number of carbon, hydrogen and oxygen atoms, but the oxygen contained is much less than that with which the carbon and hydrogen are capable of combining. Hence they afford much energy when burnt. Butter, lard, suet, olive oil are examples of nearly pure fats, but fat is a constituent of most natural foodstuffs in varying quantity. On account of their content in glycerin, fats are required in large amount for the manufacture of those explosives which contain nitro-glycerin.

Carbohydrates are so called because their composition is such that they contain carbon, hydrogen and oxygen in such proportions as to possess sufficient oxygen to combine with the whole of the hydrogen to form water. For this reason, they give scarcely more energy than that of the carbon which they contain. But, owing to their abundance, they form very valuable foodstuffs. They are met with in a variety of forms—*starch*, a prominent constituent of wheat and other cereals and of potatoes; *sugar*, of which there are several kinds distinguished by the chemist: cane sugar, found especially in the sugar-cane and in beetroot, malt sugar in malt, milk sugar or lactose in milk, glucose and fructose in fruits, honey, etc. All the natural carbohydrates are, for practical purposes, to be regarded as identical in energy value as foods, although some of them require preliminary treatment, mostly of a simple kind, by digestive enzymes, before they can be utilized by the organism.

Natural foodstuffs, especially those of vegetable origin, contain, as a rule, *indigestible matter* in greater or less amount. Although this is valueless for building or energy purposes, it has its importance in preventing constipation by the stimulating effect on the contractions of the intestinal tube. A diet consisting of materials of too digestible a nature gives trouble on this account. Hence the importance of the fibre in fruit and vegetables, the outer part of the wheat grain in whole-meal bread, and so on.

Of the three classes—protein, fat and carbohydrate—we see that the two latter may be looked upon as having the same function, that of giving energy; so that, in a diet, they may be replaced one by the other. The reasons for using both will be seen later. Protein is indispensable, because it forms part of the machinery of the living cell. But, just as we have seen that protein has also its energy value, so it appears that the cell machinery requires both carbohydrate and fat in particular forms, not only to facilitate its working, but probably also as actual parts of the machine. This, however, uses up but a very small fraction of the total consumption, which is almost entirely for energy purposes. At the same time, it would be a great mistake to undervalue the importance of substances on account of their relatively small amount, as we shall see presently.

CHAPTER IV

THE QUANTITY REQUIRED

THE following are the quantities which are generally accepted at the present time as a sufficient daily diet for a man of average weight, doing a moderate amount of muscular work.

	Weight in Grams.	Weight in Oz.	Energy Value in Calories.
Protein . . .	100	3·75	400
Fat	100	3·75	900
Carbohydrates .	500	18·00	2000

Total Energy Value, 3300 calories

Of course, the energy value must be greater if more work is done, and conversely: so that we may have such figures as these—

Light work .	3000 calories
Moderate work .	3500 ,,
Heavy work .	4000 or more calories

Since part of our food is consumed for the purpose of maintaining the body temperature, in cold weather the total calorie requirement is greater than in hot weather. Thus, according to Langworthy (1908), the average energy value of the diet of the Egyptian labourer is 2825. In the Tropics, indeed, where the external temperature may be higher than that of the body, it would clearly be of advantage if no heat were produced. But the machinery, as a whole, is not of the high degree of efficiency required for this to be the case. Heat, therefore, must be got rid of, chiefly by evaporation of sweat, but the actual production tends to be kept as low as possible by reduction of unnecessary muscular work.

It may be noticed that chief stress seems to be laid in diet tables on the energy or calorie value of the food. This is justified by the fact, already mentioned, that, if any reasonable kind of combination of foodstuffs be consumed, it will be found that, if taken in the amount necessary to afford the energy value, sufficient protein will be contained in it without further addition. Natural foodstuffs, even potatoes, contain more protein than is often supposed to be the case. Pure products extracted from parts of plants or animals, such as sugar or oil, are not likely to be made the sole articles of a diet.

We may put the matter thus:—

? "Take care of the calories and the protein will take care of itself."

On the other hand, if a large proportion of the diet is made up of sugar or fat, it may be necessary to take account of the protein value of the remainder.

Some readers may have observed that the number of calories given in the table on page 33 refer only to muscular work. They may ask, What about *mental work?* This is a rather difficult problem. The energy value of the diet for a man engaged in such work is sometimes given as the same as that of a man doing very light mechanical work.

Now, this is possibly correct, since, so far as we know, the actual consumption of energy in mental processes is not great. But there is another consideration which, as it seems to me, should be taken into account. The oxygen consumed by an organ, as we have seen, is an index of the exchange of energy therein, or, for our present purpose, an index of the food required by the organ. So far as experimental results go, it seems to be the fact that the actual consumption of oxygen in the nerve centres is not great, but, on the other hand, it has to be supplied at a high pressure. This is shown by the fact that even momentary stoppage of the blood supply causes immediate unconsciousness, although the oxygen of the blood still remaining in the brain cannot have been exhausted. It is somewhat as if we had an electro-magnet which does not need much current to actuate it, but, owing to the wire with which it is wound being of a high resistance, a high voltage is necessary to drive even a small current through. Should the brain be an analogous case, it seems possible that, although the actual consumption of food is not great, yet this food may require to be presented at a high pressure, and that to attain this high pressure it might be necessary to take a diet of an energy value equivalent to that of moderate muscular work. But this should certainly be sufficient, and the question is not yet decided.

In reckoning the food-supply necessary for a population consisting of men, women and children of various ages, it is convenient to convert the total number of individuals to some common unit. Since women and children, on the average, consume less than men, it will be clear that the number of men to which the total population is equivalent is less than the total number of individuals. A factor calculated from the average proportion of men to women and children is very nearly 0·75. Thus, the total number of "men" for whom the standard ration has to be provided is obtained with a considerable degree of accuracy by taking three-quarters of the whole population. This is known as the *man-value.*

Tables have been drawn up by Professor

Thompson (1916) and others, from returns of the Board of Agriculture and other sources, which give the total *food supply of the United Kingdom* as it was just before the War. There are, naturally, gaps in these lists, on account of the fact that the returns do not include the food consumed by people who grow it, farmers especially. This has to be estimated. But, on the whole, there would not be any considerable error on this account, and the various tables drawn up by different persons show a somewhat remarkable agreement.

Now, at the present time, it is of vital importance that soldiers in the field, and also of course the men of the Navy, should have a completely adequate supply. The following is generally taken to be such a diet—

War Ration in the Field

Protein	158 grams
Fat	200 ,,
Carbohydrate . . .	514 ,,

Energy Value, 4600 calories

The protein supply is, perhaps, rather unnecessarily high, for the reasons that will appear presently, but this is an error on the right side, in any case. The carbohydrate might possibly be increased with advantage, even at the expense of a little less meat. There is, without a doubt, a great desire for chocolate and cakes on the part of soldiers on active service. One can hardly suppose that this desire is entirely devoid of physiological basis.

After deducting that part of our food supply required for the Army and Navy, it will be found, by any one who will take the trouble to make the calculation, that what is left for the *civilian population* will supply an average diet per "man" approximately as follows—

Protein	109 grams
Fat	123 ,,
Carbohydrate . . .	514 ,,

Energy Value, 3700 calories

This assumes that the supply is not less than before the War, and it must also be remembered that the number of soldiers to be fed is increasing. The protein ration is no greater than the standard given above for moderate muscular work. While, therefore, there is no ground for alarm as regards the possibility of starvation, it will be plain that it is the duty of those who do not require so much as this to reduce it as far as possible. Any one who takes more than his share is depriving some one else of part of his. Hence the need for some kind of regulation of food consumption. But there is also, or should be, the desire to limit unnecessary expense. Anything saved by this means serves to augment the resources of the nation by enabling the purchase of War Loan, or in similar ways. We see, then, the need for the *regulation of prices* of food; and also that it is incumbent on us all to choose the sources of our food as far as possible from those of least cost.

The Belgian Food Commission.—It is of interest to consider briefly the feeding of the Belgian population by the American Commission as an application of some of the principles given in the previous pages. I must here express my admiration for the wonderful organization by which this is being done. Humanity owes a debt of gratitude to our American brethren, which it is to be hoped will never be forgotten.

The object of this Commission has been to supply to all a uniform ration of 2000 calories per day, chiefly by means of a system of tickets enabling bread to be bought at a price which enables a small profit to be made by the Commission. But other foodstuffs, such as potatoes, beans, sugar and lard, are supplied. It was found that people could be kept in health at a cost of three and a half pence per day. Owing to the excellent method adopted, the bread can be sold at a comparatively cheap rate (see *Commission for Relief in Belgium*, Report 1916, and the pamphlet by Mr. Robinson Smith, 1916).

But this diet alone is only just about the minimum required to keep body and soul together. So that, if there is an impossibility of getting sufficient supplies, as has happened in Lille, the death-rate goes up. The normal mortality of 20 per thousand rose to 30 in December 1915, to 40 in March 1916. Those, however, who are well-to-do purchase additional food for themselves, and the profit from the sale of bread is distributed to the destitute. This latter item is very considerable, owing to the magnitude of the whole undertaking. Over one million pounds profit was earned up to October 31st, 1915. It should be remembered that the work of organization is voluntary, but that there are large expenses involved in the distribution and so on. This has to be met by subscriptions from friends outside. Up to October 31st, 1915, these amounted to three and a half million pounds. The bread supplied appears to be of excellent quality. Rice and other foodstuffs can also be purchased from the Commission. Rice, in fact, is sold in Belgium at one-half the peace price. It is satisfactory to know that very strict means are taken to ensure that no part of the food finds its way to the Germans ; and, so far, it seems that escape of this kind has not occurred to any important degree. I refer to this work as an illustration of what is possible under very difficult conditions.

Actual Value of some Foods.—In order to give a concrete meaning to the figures given above for a standard diet, the calorie value and contents in protein, fat and carbohydrate of certain articles are given below.

Number of Grams required to produce 100 Calories

(28·35 grams = 1 oz.)

Butter	13·5
Cheddar Cheese	22
Sugar	24·5
Oatmeal	28
Mutton	29
Fish	67
Eggs	68
Milk	145

100 grams of *protein* are contained in—

Steak	18·5 oz.
Milk	5 pints
Oatmeal	1·5 lb.
Peas, Dried	13·5 oz.
Bread	2·5 lb.

100 grams of *fat* are contained in—

Butter	4·5 oz.

500 grams of *carbohydrate* are contained in—

Bread	2 lb. 2 oz.
Oatmeal	1 lb. 11 oz.
Potatoes	7·5 lb.
Sugar	1 lb. 2 oz.

The percentage composition of *bread* is as follows—

Water	36
Protein	9·5
Fat	1
Carbohydrate	53
Ash, etc.	1·5

Calories per pound, 1215.

The composition of bread varies somewhat, but we see that, taken in the correct quantity, it forms an excellent basal constituent of diet, being deficient only in fat.

Further particulars regarding individual articles of diet will be found below. The detailed tables in Miss McKillop's book (1916) and, for convenient calculation, the triangle method of Irving Fisher (1905) will be useful.

Minimum of Protein required.—Although 100 grams of protein is usually recognized as that of a satisfactory diet, there is evidence that, at all events for healthy individuals, this quantity may be unnecessarily large. The question is a somewhat difficult one, but must not be shirked. It has been pointed out above that all ordinary diets likely to be adopted will automatically contain as much protein as 100 grams. But should it be necessary in any circumstances to reduce the protein ration to some extent, no alarm need be felt. This conclusion is forced upon us by several facts, to which we must denote a small space. The determinations of Hamill and Schryver (1906) showed that the protein consumption of many persons during their regular work, and taking their ordinary diet, was less than 100 grams, of some as low as 76 grams. Further, from the theoretical point of view it is not easy to see why so much nitrogenous food should be necessary, since, in the adult, the only function of the nitrogenous part of the protein is to replace wear and tear. We have not very accurate determinations of what this amount actually is, but the muscular system may be fairly taken as a representative one. Now the most careful and accurate experiments show that, so long as the work does not result in excessive fatigue, no increase of nitrogen consumption can be detected (see Cathcart, 1912, p. 109). Naturally, this fact does not imply that there is no wear and tear in the muscle machinery, but that it is too small to be detected. The fuel consumed in muscular work is carbohydrate, when there is sufficient supply, although fat and even the non-nitrogenous part of protein can be utilized (see Benedict and Cathcart, 1913, pp. 71, etc.).

Some further evidence is of interest. In the feeding of pigs, it has been found that these animals may be kept on a diet free from protein for three weeks without losing weight. Fat pigs, of course, do not lead a very strenuous existence, but the heart, muscles of respiration, and the digestive organs are in activity; and in fact, a small amount of nitrogen was being continually excreted.

To some extent, the amount of nitrogen excreted on a diet of full energy value, but devoid of protein, is a guide to the amount of wear and tear of the tissues. This amounts to about 29 grams of protein per day, according to Cathcart's experiments on men.

But perhaps the most striking experiments are those reported by Hindhede (1913) from the Nutrition Institute of Copenhagen. They were made on a laboratory servant of 70 kilos weight. But, in order to apprize their value, it must be remembered that the subject was a man of exceptional intelligence, taking a great interest in the work going on, and what is perhaps of more importance, is that he appears to have been of unusually good health and strength. Another fact which greatly facilitated the experiments was, that the subject was able to live on a diet consisting exclusively of potatoes, cooked in a particular way with margarine and a little onion. This man, in one experiment, continued his regular duties for 150 days on a diet whose average calorie value was 4000, with a protein content of 29 grams, per day. In another experiment, in vacation time, he undertook hard work as mason and labourer for 95 days on a diet with an energy value of 5000 calories and a protein content of 43 grams. At the end of the experiment, the subject was in perfect health and anxious to commence another experiment. He had, however, lost altogether, on the general balance, about 35 grams of protein from his tissues. This is less than one day's consumption. The contrast between the consumption of protein in this case and the standard 100 grams is obvious. But it is probable that the result was due to the subject being an unusually strong and healthy man; and the interest of the experiments is that they show the possibility of a perfectly adequate diet containing less than one-third of the so-called standard amount of protein.

This latter ration is therefore well on the generous side, and a small reduction need not be objected to.

The uncertainty about the real protein standard necessitates caution in drawing conclusions as to the poverty of individuals from their protein consumption. In Rowntree's valuable work—"Poverty, a Study in Town Life"—the author has adopted Atwater's standard of 125 grams as the minimum protein ration, and therefore finds that 27% of the population of York are living in poverty, because their protein consumption is below this figure, a conclusion by no means justified. When the statement is made that certain families whose income was less than twenty-six shillings a week, were in an unsatisfactory state of nutrition because they consumed only 89 grams of protein, and a total energy value in diet of 2685 calories, we can hardly regard the protein as really deficient, and the calorie value could probably have been increased by the addition of some such food as oatmeal at a very small cost: if necessary, by the omission of part of the more costly form of protein.

A special value has been ascribed to protein diet on various grounds. But, if we examine these, we are bound to admit that the evidence is not particularly strong. There is a remarkable fact in connection with protein food, known by the name of "specific dynamic energy." The explanation of this behaviour has not yet been satisfactorily given. To put the matter simply, it means that when a meal of protein is taken and the total combustion of the body measured during the few hours immediately succeeding, this combustion is found to be in excess of that which could have been obtained from the protein alone. It must have increased the rate of combustion of other materials present in the organism. So far as the experimental results go, it would seem that this excess merely disappeared as heat, a result which might or might not be an advantage. It does not necessarily follow, however, that the energy is not available for other purposes, as for muscular contraction, if required, and it has been supposed that protein does in fact afford special fuel for times of unusual exertion. The experience of alpine guides, however, does not favour this view. They are known to take with them on mountain excursions refreshment such as raisins, which contain chiefly sugar and very little protein. It must be admitted that individuals differ in this respect. When taking food for a long day's walk, for example, some prefer meat sandwiches; others, of whom I am one, have far more appetite for such things as cake and fruit. From what we know to be the usual fuel burnt for muscular work, carbohydrate would be expected to be the more appropriate. Some individuals may be able to utilize the non-nitrogenous portion of protein more readily than they do carbohydrate. A difficulty in regarding protein as valuable in affording energy in times of strain is that there is no storage of it in the body, except in the form of increase in the actual structure of the organs and tissues. In this respect, it differs from both fat and carbohydrate. Any special value it has must be manifested while it is being absorbed from the alimentary canal.

It has also been stated that a danger of a low protein consumption is a liability to suffer more from infectious disease. But no definite evidence has been brought forward to show that this is the case.

On the whole, it seems that it would be perfectly safe for healthy people to limit their protein consumption to some extent, even below the standard 100 grams. Those in less robust health should proceed carefully. In any case, it is probable that at first some degree of discomfort might be experienced, as indeed would be the temporary result of any reduction in the total amount of food consumed.

There is one point with regard to which erroneous statements are sometimes made. That is, that the products of the chemical changes which protein undergoes in the body are injurious or poisonous. This is not so. Urea is a perfectly innocuous substance, devoid of active chemical properties. So is uric acid, notwithstanding the nonsense of newspaper advertisements. Although uric acid is found in gouty deposits, there is no reason to suppose that it is the cause of the general disorder of nutrition known as gout.

Turning next to the two sources of energy, we may note that it is possible to supply all the energy required by means of either fat or carbohydrate, so that we may ask, Why do we take both?

The *use of carbohydrate* is fairly obvious on the ground of its cheapness, but there is also reason to believe that it is of great importance, if not essential, to the utilization of proteins (see Cathcart, 1912, p. 116). It has, indeed, been suggested that this is the reason why in diabetes, although carbohydrate is carefully withheld, nevertheless the organism continues to produce sugar out of other materials.

The chief *value of fat* is in the ease with which it is stored, almost in unlimited quantity, chiefly in the so-called connective tissue which fills up spaces between organs in the body and forms a layer under the skin. Although carbohybrate is also stored, in the form of glycogen, a kind of starch, in the liver and muscles, this takes place only to a limited extent. We notice that both these foodstuffs, fat and carbohydrate, enable a store of reserve material to be kept for use when required to give energy.

Although, however, the fat of food is easily stored, the experience of farmers in fattening cattle shows that fat is formed out of carbohydrate. Therefore, even on a carbohydrate diet, a store of fat may be laid up. It is perhaps not so easily done as from fatty food.

Fat has another advantage over carbohydrate in that, weight for weight, it has a higher energy value; but this, of course, could be compensated by consuming a somewhat larger proportion of the carbohydrate diet.

It is sometimes stated that fat is more easily digested than carbohydrate. This depends on the particular kind of each taken, especially as regards its physical condition or subdivision. For example, the fat in milk is probably more digestible than raw starch, but it is very unlikely that cold mutton fat is more easily digested than sugar. Pavlov showed that fat in the stomach retards the secretion of gastric juice. Neither carbohydrate nor fat is digested, to any important degree, in the stomach itself, but both are rapidly attacked by the pancreatic juice in the small intestine. The sugar, especially, which is produced, is rapidly absorbed, whether it comes from the starch or from the sugar of other kinds in the food. When the stomach is not in a healthy state, both carbohydrates and fats in large amount are apt to cause indigestion, the sugar being easily subject to a fermentation by microbes present. An irritable stomach does not like the presence of matter which it cannot digest.

On the whole, it would appear that the practical value of fat consists chiefly in its use in cooking. Very few attractive dishes could be made without it, and we shall find presently how important is the fact that food should be eaten with relish. But, in any case, it is rather difficult to understand why the scarcity of fat is so severely felt in Germany.

I am unable to follow the objections taken by some to the use of sugar as a food. Undoubtedly, when carbohydrate is taken in the form of natural grains or roots, other valuable substances are taken with it. But the starch present is all converted into sugar before being of any service to the organism, while the other constituents, so far as they are necessary, can be obtained elsewhere. There is no reason to reject sugar as a valuable foodstuff, so long as it does not make up too large a proportion of the total energy value of the diet. In fact, any objection to it can only be of a negative kind.

CHAPTER V

ACCESSORY FACTORS, OR "VITAMINES"

THERE are certain essential constituents of an adequate diet to which, as yet, no reference has been made. Although they are present in very small amount in most natural foods and their chemical nature is unknown, healthy life is impossible in their absence.

They are best called "accessory factors." Unfortunately, the name "vitamines" was given to them under the mistaken impression that they had been separated in a pure state from foods, and that their chemical nature had been determined. The name has come into use, even in the daily Press. If used, it must be understood that the substances referred to are not "amines" in the chemical sense, and the word must be taken as a mere name, not conveying any meaning by its derivation.

It was discovered by Captain Cook (1776, p. 405) that, in order to preserve the health of his crew on long voyages, it was necessary for them to take every opportunity of obtaining fresh food. The preserved food taken on the ship was deficient in something. The passage in which Captain Cook describes his experience is worth quoting—

"We came to few places where either the art of man or nature did not afford some sort of refreshment or other, either of the animal or vegetable kind. It was my first care to procure what could be met with of either by every means in my power, and to oblige our people to make use thereof, both by my example and authority; but the benefits arising from such refreshments soon became so obvious that I had little occasion to employ either the one or the other."

Further discoveries in this field are of comparatively recent date. Stepp found, in 1909, that alcohol removed something from bread and milk, so that it was no longer able to serve as food for rats. When, however, the alcohol was boiled off from the extract, the residue, even in small quantity, added to the inadequate bread and milk, restored its value. Hopkins, in 1912, showed that a diet of purified foodstuffs was incapable of serving as a food for growing rats, but that the addition of a minute amount of fresh milk made the same diet altogether satisfactory. Subsequent investigations showed that the substances concerned are to be found in fresh food of all kinds, vegetable and animal, and that they will stand a certain amount of boiling or heating, so long as the medium is not alkaline. They are apt to be destroyed by long preservation, although some are stable in acid solutions. Lime-juice, which is strongly acid, is well known to retain its protective power against scurvy, which is one of the results of absence of the accessory factors, for a considerable time. There is evidently a variety of these accessory factors; for example, there is one in the outer coat of rice which prevents the occurrence of the disease "beri-beri," caused by the exclusive use of polished rice.

Further, there is evidence that they may be divided into two groups, neither of which is effective for growth without the other. McCollum and Davis (1915) find that rats will not grow on polished rice, even if wheat germ be added; nor will they grow if butter alone is added. Both together made the diet an adequate one. That contained in wheat germ is soluble in water, not in fat, and may be called the "water-soluble B factor," the other is the "fat-soluble A factor." From Hopkins's experiments, fresh milk must contain both of these.

It has been noticed in experiments on the effect of absence of these factors, that the deleterious effects do not come on at once. They are subject to a delay of some days. This shows that they do not rapidly disappear, although they must be present in very small quantity. The fact indicates that they do not undergo chemical change, like the foodstuffs properly so called. The way in which they act is unknown, but the chemist will be reminded of the phenomena called "catalytic." The mode of action of the digestive agents known as "enzymes" is also catalytic.

An interesting fact is that plants are dependent for normal growth on similar factors. The first case in which the question was investigated was that of yeast, by Wildiers in 1901. This work was done at the ill-fated University of Louvain, whose wanton destruction has aroused the execration of all civilized nations. The more recent work of Bottomley indicates that these plant factors may be destined to play an important part in the cultivation of vegetable foodstuffs.

The practical application of the facts described in this section is that in a diet composed of a fair variety of foodstuffs, inclusive of fresh vegetables or fruit, there is no risk of absence of the necessary accessory factors. But when a monotonous diet is taken, such as rice, it is important that the material should not be too much prepared by artificial means, such as the polishing of rice to produce a white appearance.

CHAPTER VI

DIGESTIBILITY

THERE are many constituents of foodstuffs as bought which are not digested at all, although, if burnt in air, they are capable of giving energy. This has already been mentioned incidentally. Materials of this kind are the cellulose constituents, woody fibres and so on of plants and some parts of the fibrous or tendinous parts of meat. These, of course, must not be reckoned as components of the daily ration. They have their value, however, in promoting intestinal movements.

There are also some constituents which are only partially utilized, because they are not quickly digested and do not remain long enough in the alimentary canal to be fully acted upon. Such are the proteins of nuts.

In giving to such proteins their proper value, therefore, it must not be reckoned as that of the total content in protein, but only some 80%of it. Tables in which the proportion digested of various foods is shown will be found in Lusk's book (1909).

Many facts of practical importance have come to light through Pavlov's experiments (1910), especially as regards gastric digestion. In the first place, it was found that the mere presence of food in the stomach was insufficient to excite secretion of gastric juice, except after some considerable time. The chief stimulus is that the food should be approached with *appetite*, the stimulus being conveyed through the nervous system. Without appetite, scarcely any gastric juice is formed. When Macbeth wishes for his guests that good digestion may wait on appetite, it seems that he was stating a truism. The value of attractiveness in food preparations is shown hereby, as is also the mistake made by some well-meaning food reformers who would wish to confine us to plain food. Of course, mere ornamentation of cakes and confectionery is wasteful of time and material, but variety in form and flavouring, as also in mode of preparation, is to be approved of. This would especially apply to the present time, when it is desirable to limit the consumption of meat.

It is important to distinguish between *hunger* and appetite. The former, as shown especially by Carlson (1916), rests upon sensations derived from muscular contractions of the empty stomach. The latter is rather an anticipation of pleasures to be obtained from sensations of taste. Hunger, as Carlson remarks, is probably never felt by many people at the present day, because the physiological state is absent. The gastric contractions in question originate in the stomach itself and are of quite a different nature from those which take place during the process of digestion. These latter serve to bring in turn all the food under the action of the digestive juices, and, in due course, propel it into the next following section of the alimentary canal.

It was mentioned above that, although the presence of food in the stomach by itself alone does not lead to any immediate secretion of gastric juice, after a time some secretion appears. This is due to the direct effect of products of digestion and is produced also by introduction of meat extracts and other substances into the stomach. The use of soup to commence dinner with finds its justification in this fact, especially when fatigue has blunted the appetite. Perhaps bitters or vermouth may sometimes be useful under such conditions, but alcohol in any form must be regarded as an aid of psychical import only. Its direct effect on all digestive processes is a retarding one. Carlson (1916, pp. 293 and 297) shows that bitters, used medicinally, neither increase hunger nor produce any effect on the amount or activity of the gastric juice.

There are one or two erroneous impressions as to the value of some particular foods that need correction.

The first of these is that raw eggs are more easily digested than cooked ones. The contrary has been shown by careful experiments to be the case. Of course, if the white is boiled hard, it must be finely divided by chewing, otherwise the gastric juice can only attack it slowly from the outside. Probably the best form is that of custard. The reason why raw egg-white is difficult of digestion is that it contains something, in small amount, which has a powerful retarding or inhibiting action on the digestive enzymes. This is destroyed by heat.

Arrowroot and cornflour are popularly supposed to be specially digestible foods for invalids. In fact, they are chiefly starch, and apparently no better than other forms of starchy food. Very little protein is contained in them. Gelatin, again, is not a complete protein and should not be relied upon to any extent to replace true proteins. These considerations are of importance in feeding patients recovering from any wasting disease. It will be obvious that they require plenty of material to build up the tissues that have been lost.

Fatty substances are not digested in the stomach and, as Pavlov showed, tend to oppose the secretion of gastric juice. In a healthy stomach, and especially when in a finely divided state, as in milk and cream, they produce no disturbance and are easily digested in the small intestine. This applies, as is well known, even to the case of illness.

CHAPTER VII

ALCOHOL

At this point some further remarks with regard to the use of alcoholic "stimulants" are necessary.

Some intemperate advocates of Temperance have unfortunately done harm to their cause by making statements which their opponents are able to disprove. One of these is the denial that alcohol is in any sense a food.

Its energy value, when burnt outside the body, is high, amounting to 708 calories for 100 grams as against 400 for carbohydrate or protein. It has been stated that it is not burnt in the body, or only to a very slight extent. This is not true. It is excreted unaltered in small amount after considerable quantities have been taken, but by far the greater quantity is oxidized to afford energy.

The real objections to its use are of another kind and chiefly on account of its action on the brain before it has had time to be burned up. Although it appears to be a stimulant, this impression is due to an incorrect interpretation of the effects observed. It is really a narcotic. One of the most striking facts with regard to the activities of the highest parts of the brain is the great predominance of the inhibitory mechanisms, by which the bringing into play of inappropriate movements or sensations is kept in check. Now, these mechanisms themselves are extraordinarily susceptible of being abolished by extraneous influence of various kinds. One of the most powerful of these influences is alcohol. When, therefore, greater liveliness is experienced under its action, it is because alcohol paralyses the inhibiting mechanisms and not because it excites activity by a true stimulating action. There are, on the other hand, certain substances which appear to be genuine stimulants. Such are caffeine, a constituent of coffee and tea, and perhaps some of the substances found in meat extracts. Liebig's extract, for example, contains very little real food. Cocaine, in small doses, has also a stimulant effect on the brain, but it must on no account be used for this or any other purpose except for local anæsthesia, and indeed it is only required for this purpose in very rare cases, since other drugs, such as novocain, serve the purpose equally well. The cocaine habit is easily formed and soon makes a total wreck of its victim, body and mind. Some proprietary articles sold for asthma and other purposes sometimes contain cocaine and should be warned against, although the present restrictions make it difficult to obtain them.

An experiment made by Pavlov in his investigations of the activities of the brain shows how readily an act in which inhibition plays a part can be upset by a removal of the inhibition. It was this: a particular bell was rung in the hearing of a dog. Two minutes afterwards food was given. The giving of the food was accompanied, as usual, by the secretion of saliva. The process was repeated for a number of times and then the bell was rung without the subsequent presentation of food. Nevertheless, after the due interval of two minutes, saliva appeared. It is clear that something must have been going on in the brain between the hearing of the bell and the secretion of saliva, but that the result was prevented by inhibition from showing itself. That this was the case was proved by the fact that the inhibition could be removed by the application of some indifferent stimulus, such as a touch, to the animal's body. Such a stimulus is not by itself associated with the secretion of saliva. But, if it be applied during the interval of two minutes spoken of, the saliva appears immediately, instead of waiting for the lapse of the proper time.

The narcotic effect of alcohol on the brain is also shown in other ways. After even small quantities, the ability to add figures correctly is decreased, although the subject believes that he is doing it unusually well. Moreover, the effect lasts for as long as twelve hours or more.

Another false idea is that alcohol warms. This is due to the fact that it dilates the blood vessels of the skin; and, since the feeling of warmth arises from the skin, if this is warm, the mistaken impression is given that the body is warm. In point of fact, the general temperature is lowered, owing to the increased loss from the skin.

Alcohol also has been shown to lower the resistance to infection.

Finally, visible changes have been found in the brain-cells of drunkards, so that there is every reason to believe that similar changes in a less degree will be produced by even comparatively small doses of alcohol.

Enough has been said to show that there is no benefit of any kind to be derived from the use of alcohol. Any reason for taking it must rest on other grounds, which do not concern us here.

Since this is so, if there is likely to be any shortage of food, the first prohibition to be made ought surely to be the use of materials capable of serving as food from being used in distilleries, and, to a less extent, in breweries. For the manufacture of alcohol as a solvent for explosives, materials unfit for use as food, such as bad potatoes, can be used. There is also a large store of new whisky in the warehouses.

Further information on the subject of the action of alcohol may be obtained from Cushny's *Pharmacology* (pp. 131–155).

I cannot help expressing regret that any apology for the use of alcohol, such as that in a recent number of the *Church Times* should have been published. At the present time, especially, excuses for the waste involved in the use of alcohol should not be given. The argument that it is a "gift from God" would apply even better to opium, which is a more natural product than alcohol. It is admitted that opium should be confined to medicinal use and the same limitation should be applied to alcohol. Even for medicinal use there are better substitutes. I cannot understand how any but an ignorant person can deny that there is great waste of good food involved even in the manufacture of beer, apart from the waste of fuel and labour. There is always "degradation" of energy in the fermentation process. To make potable spirit, materials useful for food, such as barley and potatoes, must be used. A religious paper should be the last to advocate what is, to put it in the most favourable light, nothing but a selfish indulgence.

The head of a large sanatorium has written to me, without a request on my part, to say that he is greatly concerned about the number of cases that come to him, even of men of much value to the nation, whose efficiency is seriously impaired by the use of alcohol.

From the physiological point of view, an advertisement which appeared in *The Times* of December 21st, 1916, is distinctly misleading. Nothing can alter the fact that there is a loss of energy in the change from carbohydrate to alcohol. If the barley referred to were consumed directly by man and cattle, the energy value obtained would be greater than if all the products resulting from its use in making beer were consumed. It is doubtless true that very little sugar is added, as such, in the manufacture of beer, but the starch of the barley is converted into sugar in the process and part of its energy value lost by fermentation. So far as "temperance drinks" contain sugar, they have, of course, a food value; and I fail to see where the waste, stated to exist in such drinks, occurs. As for the sixty million pounds contributed by the "trade" to the revenue, surely the sum available for national objects would be greater still if the consumer saved what he spends on alcoholic drinks and invested it in War Loan, while he would himself have the benefit of the investment.

CHAPTER VIII

VEGETARIANISM

PERHAPS one of the most widely spread errors in reference to food is, that there is some special virtue in butchers' meat. Sometimes it appears to be thought that there is no protein in vegetable foods. This, as we have seen, is not the case.

Vegetable foods, *if properly chosen*, can supply all that is necessary for a complete diet. The protein is not quite so easily digested, but more of the food can be taken in compensation. The proper choice, however, may be the most difficult thing, since it is not an easy matter, unless some animal product, such as milk, is added.

The work of McCollum, Simmonds and Pitz (1916) shows that an adequate diet for rats can be made from the three natural vegetable foodstuffs, wheat, wheat-germ and rice. But another mixture, although containing a larger number of constituents, was unsatisfactory. Further, it does not follow that the mixture suitable for rats would be so for other animals or man. The conclusion drawn is that a diet of purely vegetable origin cannot be safely made up until more is known about the properties of each natural foodstuff. It is certain, on the other hand, that all the components of a successful diet can be found in foods of plant origin.

CHAPTER IX

EXERCISE

It has been recommended that the amount of exercise taken for pleasure should be lessened. This suggestion is made on the ground that " the need felt by many for constant exercise is in part due to the fact that the food eaten is in excess of what, without the exercise, would cover the needs of the body."

While this may be so to some extent, universal experience of the benefits derived from exercise suggests that the consumption of slightly more food may be more than compensated by the increase in general efficiency,

The actual increase in the energy supplied by food necessitated by, say, two or three hours' exercise once a week, is a small fraction of the total consumption. It is to be admitted that there is a possibility that the increased appetite resulting from exercise in the open-air may lead to a consumption of food greater than really necessary. This however, when recognized, may be guarded against.

The way in which exercise produces its effects is a difficult matter to express an opinion upon. It is possible that it may be analogous to that of fresh air or a cold bath. The stimulation of peripheral nerves in an unusual manner wakes up, so to speak, the nervous system. The use of muscles, which have been more or less idle, serves also to keep in adjustment the various mechanisms of complex movements ready for every-day requirements when needed.

But, while it is doubtless true that "all work and no play makes Jack a dull boy," it is none the less true that "all play and no work makes Jack a fool." The latter part of the proverb may be commended to the devotees of the cult of exaggerated athleticism that one sometimes meets at the older Schools and Universities.

Of course, the remarks about muscular exercise have no application to those engaged in muscular labour as their ordinary occupation. The form of recreation required by these is rather of a different kind, such as music, reading, etc. It is not to be supposed, however, that change of occupation of any kind is without its value to any one, whatever his regular work may be.

CHAPTER X

THE VALUE OF COOKING

FROM what has been said above as to the destructive effect of heat on certain accessory factors of diet, it might be supposed that the process of cooking is to be deprecated. We have also seen, however, that the digestibility of some foods is improved by it, owing to the removal of certain substances which prevent the action of the digestive enzymes.

Another beneficial effect of cooking is to kill micro-organisms and other parasites.

But perhaps the greatest use of the art is in the preparation of dishes attractive to the palate and other senses. As we have seen, appetite plays a very important part in digestion, owing to the secretion of gastric juice, which is produced in the stomach, ready for the reception of food.

The destruction of accessory factors can always be compensated for by taking fresh fruit or vegetables.

The book by Kinne and Cooley (1916), although primarily intended for use in schools, will be found to contain a number of useful instructions, both in cookery and with reference to the preservation of food.

CHAPTER XI

CHARACTERISTICS OF CERTAIN ARTICLES OF DIET

Sources of Protein.—Meat, poultry and eggs are the most costly form of protein, even in peace times. Corned beef is cheaper, but may be deficient in accessory factors. The cheapest source of animal protein is separated milk or cheese. The cheapest vegetable source is oatmeal. It must again be insisted on that protein can be obtained equally well from either animal or vegetable source.

Fish, curiously enough, when allowance is made for the large percentage of water which it contains, does not turn out to be a cheap source of protein. The cost of transport to inland towns helps to make it more costly.

As regards food in general, it should be pointed out that an extra price is too frequently paid for mere appearance, white rice and the cheaper grey kind are equally valuable. Special named foods made by particular firms have rarely any advantage over the ordinary market varieties.

Bread.—Notwithstanding the agitation some years ago by certain newspapers, it is remarkable how little difference there really is between the nutritive values of white bread and the so-called "Standard" bread. It appears that the extra protein obtained by using a larger proportion of the wheat grain than is done in white flour is comparatively indigestible. The difference is greater in some kinds of wheat than in others; but, when allowance is made for digestibility, very little is gained. The value of the new National flour, and bread made from it, consists chiefly in the fact that a larger number of loaves can be made from the same amount of wheat without diminishing the food value. Even as much as 90% of the wheat can be made into flour, but 8% of this flour is indigestible husk. This husk has a value in avoiding constipation, as pointed out above, but no nutritive value. The experience of the Food Commission in Belgium is in favour of at least 82% milling, which makes a yellowish bread. The slightly less nutrient value compared with that of 65–70% milling is more than counterbalanced by the lower cost, so that more value can be obtained for the same price. It will be remembered that our new Government regulation fixes the standard of milling at 76%, which also makes a rather yellowish bread. The colour is due to the inclusion of more of that part of the grain from which the future wheat plant would grow, if the wheat were sown. It is commonly known as the *germ*, for this reason.

Some objections have been made to the inclusion of more germ than in white flour. It is said to be more difficult to make light bread. And the flour is more inclined to be spoilt by keeping. On the other hand accessory factors are contained in the germ, although this may not be of great importance if a variety of other food is taken.

The Belgian Commission point out that

11% of maize flour (American corn flour) can be mixed with the wheat flour to advantage. It increases the quantity and slightly reduces the cost per kilo (Robinson Smith, 1916, p. 7).

It will be realized that the statements of some advertisers in the daily papers can only be described as misleading and mischievous nonsense. It is stated, for example, that a particular bread is made from the whole of the wheat and consists of 100% of perfectly digestible material, while the Government by fixing the standard at 76% has eliminated 24% of the most nourishing part of the "berry" [*sic*]. This is absurd.

As we have seen above, bread with the addition of some fat, is a complete food in itself. Hence the popular "bread-and-butter." Speaking for myself, I would almost as readily take jam as butter, so that, at a pinch, even the fat might be eliminated. I agree also with Wood and Hopkins that we do not, in England, make sufficient use of the numerous different varieties of bread, rolls, etc. Bread may also be consumed as toast, hot or cold, or with jam, butter, dripping and other things. All of these may assist in the proper appreciation of its value.

Oatmeal.—This is not nearly enough made use of in the South. Weight for weight, it contains more protein and more fat than wheat does. It seems difficult for the inexperienced to make good porridge. Oatcakes are a valuable form in which oatmeal can be taken.

Rice.—As already mentioned, there is no advantage in using white "polished" rice. In fact, where it is the staple article of diet, the polishing removes an essential accessory factor ; so that a disease called Beri-beri results from its exclusive consumption. The Belgian Commission regards rice as the cheapest of nourishing food for the feeding of a population on a large scale.

Sugar is too often regarded rather as a flavouring or sweetening agent than as one of the most valuable energy-giving foods. It should be remembered also that, as purchased, it consists of practically 100 per cent. available material. This refers to cane-sugar, or, what is the same, beet-sugar. In the form of treacle, it is not, of course, quite so pure.

It appears that "golden syrup" consists mainly of that kind of sugar called by the chemist *glucose.* A preparation of this sugar, not chemically pure, is being sold for domestic purposes. There appears to be some undeserved objection to it, apart from its flavour, which would prevent its use for some purposes. In point of fact, when we digest cane-sugar, half of it is converted into glucose. Possibly there may be an idea that commercial glucose is not sugar at all.

The sugar present in fruits is glucose, while that in the reserve dépôts of the stem and root is cane-sugar, or saccharose, to give it the chemical name. Glucose is not so sweet as saccharose.

The chemical compound known as "saccharin" is not a foodstuff, and must not be supposed to be a substitute for sugar.

Fresh Fruit and Vegetables.—The chief

value of these consists in accessory factors. In the East End of London the only fresh vegetable food used by the majority of the poorer population is fruit, and mainly oranges. We see, from this fact, the justification of the protests raised against the restriction of the import of oranges.

Milk.—This, as remarked already, is one of the cheapest sources of protein, actually the cheapest source of animal protein. Wood and Hopkins point out the waste involved in not making more use of separated milk for human food, but its bulk involves difficulties of transport.

At a time when 1000 calories in the form of meat cost one shilling, the same amount could be obtained from milk at a cost of fourpence three-farthings.

Condensed milk is not economical.

Butter and Margarin.—While butter is the most digestible form of fat, margarin may well take its place for most purposes.

The only objection to the better qualities of margarin is their lack of taste and vitamines. But this is preferable to the objectionable taste of the inferior qualities. Whether this is due to an attempt to imitate the taste of butter, or to something present in the raw materials, I do not know. Whatever it is, it would be better absent.

CHAPTER XII

POSSIBILITIES OF ECONOMY

IN order to obtain some idea how economy might be effected, it will be instructive to examine some typical family budgets. I take these from the data given in the book by Wood and Hopkins. They rest upon careful measurements of actual consumption, and may be taken as representative of the state of things before the War.

Taking, in the first place, the case of fourteen families in York, as investigated by Mr. Rowntree. The average income of these particular families was less than 26*s.* per week. Their average consumption, per "man," was 2685 calories, and the protein in the diet amounted to 89 grams. All that may be remarked about this diet is that the energy value is undoubtedly low, and that better value might possibly have been obtained at the same expense if part of the protein had been replaced by carbohydrate. But there is the uncertainty as to how large a proportion of the individuals might have been growing children, who would require more protein than the adults do.

Next, let us take a family with a higher income, that of a foreman earning 38*s*. a week. The food consumption per "man" amounted to 145 grams of protein and 4800 calories. The details of the budget will be found in Wood and Hopkins, and it would seem that some diminution both in protein and energy value could be effected without detriment, especially in protein.

Passing on to an income of £150 to £200 a year, the values are 140 grams protein, 4250 calories. A further case is that of a family keeping three servants. Here the values are 143 grams protein, 4379 calories. On this last case, Wood and Hopkins remark that the total food might be reduced by one-sixth and part of the meat consumed might be replaced by cheaper sources of protein, such as bread or oatmeal. They conclude that, while the poorer classes cannot make any retrenchment in food expenditure, the wealthier classes might save 10 per cent. of the whole national expenditure on food. This saving would amount to at least sixty million pounds per annum, no mean figure.

It is interesting to compare the amount of food obtained for one shilling by different classes of the population before the war :—

	Labouring Class.	Artisan.	Wealthy.
Protein . . .	179	140	92
Calories . . .	5500	4250	2850

The conclusion to be drawn from this table is that those who have been accustomed to consume their protein in the form of meat might advantageously replace part of it by the cheaper vegetable sources of protein. It might not perhaps be advisable to replace the whole of it: the 4 oz. standard might be divided up somewhat as follows—

1 oz. as meat.
1 oz. as milk.
2 oz. as oatmeal, bread or beans.

The actual necessary amount of food is less than is usually supposed, if we take the food budgets of the wealthier families given above as an index of the general practice in such cases.

It must be admitted that it is a matter of some difficulty for any household to work out with any degree of accuracy what its consumption is. It can probably be estimated most easily by averaging the purchases of food during a period of several days, the longer the better, and calculating their value from Miss McKillop's tables (1916). The work will be found by no means devoid of interest. But the real "man value" of a household is a matter of some uncertainty. Certain members take lunch away from home, and friends or relatives on leave come in at various times. With a little trouble, however, these factors can be given their due arithmetical weight, without much inaccuracy.

In a household of few persons, it is naturally a simpler process, but the result would probably be more subject to the errors incident to individual peculiarities. The wealthier classes, however, apart from any calculation, may take it that they may, without any disadvantage or risk, attempt to reduce their expenditure on food by one-sixth—in some cases by replacing expensive articles by cheaper ones, in other cases by diminution of quantity.

It is probable that a diminution in the daily ration would, at first, be attended with some degree of discomfort, but benefit would soon be felt. The main object of the present book is to show that it can be done without risk to health. Those who wish to economize for patriotic reasons will be ready to accept the small initial discomfort the more easily when they are satisfied that no harm will result.

It has been noticed that Irish peasants, used to the consumption of voluminous rations of potatoes, have complained of hunger, and even of starvation, when given food of greater value, but of smaller bulk.

Similarly, Bavarian peasants, used to bread, complain if given a diet of meat.

The *change of any habit* is apt to cause at first a feeling of want, which disappears subsequently. Some old observations show how ancient habits with regard to consumption of food are adhered to. I refer to Dutch settlers in Java, whose consumption of food was found to be the same as in Holland, although the conditions of a tropical climate imply that less is required.

One of the most pressing needs at the present time is a *control of the prices of food and a means of ensuring equality of distribution*, the latter especially in the case of sugar. Many dealers in foodstuffs appear to think themselves justified in exacting as high a price as they can get their customers to pay. The experience of the Food Commission in Belgium suggests that prices are unnecessarily high here in England, particularly in the case of bread.

A reduction in the consumption of food is probably only to be obtained, to any notable extent, by the voluntary efforts of patriotic citizens. Attempts at control from outside do not promise well, if we may judge from the results of the recent limitation of meals in restaurants. The effect of this has been, so far as we can see, to increase the consumption of meat and to decrease that of sweets, precisely the opposite of what is desirable. We must, however, all of us assist the Food Controller in his very difficult task by cheerful acceptance of the conditions which he feels it necessary to impose. No doubt, suggestions made with the desire to help, and not to find occasion for carping criticism, will be met with welcome and receive careful consideration.

CHAPTER XIII

GENERAL CONCLUSIONS

By way of summary, we may conclude with the aphorism already given—

"*Take care of the calories and the protein will take care of itself.*"

But we must also remember that the number of calories really necessary is by no means so great as it is frequently imagined to be.

The *accessory factors*, again, like the protein, do not, as a rule, require special consideration. At the same time, it is well to ensure their presence by taking fresh fruit or salad. These are practically the only uncooked food taken in this country, with the exception of milk. Oysters can scarcely be regarded as a regular article of diet.

With respect to the substitution of a part of the animal protein, usually taken, by its equivalent in the vegetable form, it is of some importance to refer to what has been pointed out in connection with the *use of farm land.* It appears that more food per acre can be obtained by growing wheat than by using the land as pasture for sheep or cattle. There are, doubtless, economical reasons why the farmer hesitates to make the change, but the fact must be kept in mind.

As to the necessity for *economy in the use of wheat and other cereals*, the Report of the International Institute of Agriculture in Rome, with regard to the crops of 1916, is to be considered with care. The wheat crop of 1916 turns out to be only 93·4% of the average; but there are remainders from 1915, which was an exceptionally good year. There are also to be added some crops from the Southern Hemisphere reaped in December and January. On the other side, the Report points out that there is likely to be an increase in consumption owing to improvements in economic conditions, movements of population, arrival of armies, increase of rations to mobilized units, etc., and the conclusion is drawn that "considerable drafts upon the remainders mentioned must be made in order to bridge over the interval" up to the harvest of 1917. "It is therefore both urgent and indispensable to effect serious economies in consumption. Otherwise available supplies at the end of the current season would be much reduced and might even be insufficient if next harvest should not prove to be a plentiful one."

It may be well to refer, finally, to the fact that no attempt has been made in this manual to deal with special food required in *disorders of nutrition.* That is the province of medical science, which deals with the diseased organism, while physiology deals with the activities of the normal healthy organism, plant as well as animal. Physiology is thus the foundation not only of medicine, but of hygiene and also of agriculture. I call attention to this because it is sometimes thought that a knowledge of physiology is only necessary for the student of medicine. Since it deals with the normal activities of our bodies as they are used every day, it should be obvious that some knowledge of it is of vital importance to all of us and ought to be possessed by all of us. One of the problems of physiology is that of food, and an elementary account of this problem has been attempted in the preceding pages.

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