I know that great exertions are being made to establish a Library at Nottingham.

It has been intimated to me that the Local Government Board in London would supply to a Library at Newcastle some works and official papers, but with the stipulation that they should be properly provided with a suitable place, and be preserved and maintained for the use of those who take an interest in Sanitary Science.

On behalf of the Sanitary Institute I beg to present to the Free Library of Newcastle the books accompanying this paper.

Mr. C. S. Smith proposed a vote of thanks to Mr. Grantham for his paper, and also for the presentation he had made as the nucleus for a library.

Mr. T. P. Barkas seconded the motion, and said that they had in the town two libraries, one of which was one of the finest in the United Kingdom. They were about to spend £5,000 on books for the reference library now. He thought it would be best that these volumes should be given to the public library.

Mr. E. C. Robins, F.S.A., pointed out that the Government would probably be much more liberal to public free libraries than they would to subscription libraries. The chance of getting blue books and reports would be very much stronger in the one case than in the other.

The vote of thanks was then carried, and Mr. Grantham replied.

THE FOOD AND ENERGY OF MAN.

A LECTURE

By Prof. F. S. B. F. de Chaumont, M.D., F.R.S.

CAPT. DOUGLAS GALTON, C.B., F.R.S., IN THE CHAIR.

Although eating cannot be said to be in any way a new fashion, it has nevertheless been reserved for modern times, and indeed we may say the present generation, to get a fairly clear idea of the way in which food is really utilised for the work of our bodily frame. We must not, however, plume ourselves too much upon our superior knowledge, for inklings of the truth, more or less dim, have been had through all ages, and we are now stepping into the inheritance of times gone by, using the long and painful experience of our predecessors as the stepping stone to our more accurate knowledge of the present time. In this, as in many other things, we are to some extent in the position of a dwarf on the shoulders of a giant: the dwarf may, indeed, see further than the giant, but he remains a dwarf, and the giant a giant.

There is an old saying that "an army marches on its belly," by which no invidious comparison to snakes, or otherwise, was meant, but merely that soldiers must be fed if they are expected to do useful work. During the great wars of the early part of this century it used to be a common joke among the French that you should never ask an Englishman if he has fought well, but if he has dined well, and then you could be secure of his fighting. Many a true word is spoken in jest. On the other hand, many have affected to despise food, like the hero of Tennyson's "Maud," who complains that he has even to care for "wretched meat and drink;" or, like the modern æsthetic school, who profess to dine off the contemplation of a poppy or a lily, or it may be, a sunflower. Food is said to be a gross thing; but, then, so are coals, working in which is not conducive to refinement or delicacy of appearance—but without coals, where should we be? either in this *omphale* of terrestrial carbon, or anywhere else! The same with food; it may not be æsthetic to be seen consuming a beef steak, or bacon and greens, or even porridge and milk, but without these or their like, neither coal whipper nor æsthete would come to much good. Poetry is a beautiful thing, but the poet himself must come off his winged steed, and humbly acknowledge that he and his charger owe both their poetry and any other manifestation of energy to the food they have professed to despise and hold as exceedingly vulgar and material.

I do not mean to say that the time will come, still less that it is near, when we shall be able to feed poets as our great graziers do cattle, and so cultivate a pastoral or didactic, a humorous or an "Ercles" vein, by particular kinds of feeding,—but the thing is not preposterous,—it is conceivable, and the time may come when its possibility may be considered to be within measurable distance. The results of the Darwinian views of development and natural selection have been to show that the progress of all animals, man included, is most largely influenced by the ease or otherwise with which abundant and appropriate food may be obtained. Every thing seems to indicate that the most rapid advances towards civilisation, that is, the quickest development of the higher faculties, has taken place in the warmer regions of the earth, where food was abundant on account of the genial influence of a tropical or subtropical sun. When crowding became excessive, and food proportionately less easy to obtain, migrations to colder regions took place, arising from stress of circumstances, for the purpose of seeking "fresh fields and pastures new." There seems no reason to believe that man orignated at more than one centre, and it seems more reasonable to think that Eskimos and Lapps were driven to the circumpolar regions, than that they voluntarily selected such a dreary life, amid circumstances so adverse and arduous. This view is also supported by ethnological considerations.

By looking now at the histories of the races of man, we may learn the lesson that, when things are made too easy, man is inclined to fall away and deteriorate. The ancient tropical civilisations have gone to decay, and the nations that boasted them have either disappeared from the face of the earth or bow their heads to the yoke of the stranger. On the other hand, if things are made too difficult, man's development is arrested, as in the circumpolar regions. But, when the difficulty is not greater than can be successfully overcome with a fair amount of expenditure of energy, a high development is possible, both physically and intellectually. Hence, the masters of the world come from the temperate regions, where the forces of nature may be successfully grappled with, but where they neither succumb too easily nor oppose man's efforts too severely. In countries where the soil only requires to be "tickled with a hoe to laugh with a harvest," man is only too prone to enjoy his "keff," as the Eastern calls it, and more or less to dream the happy hours away; and,

> "Propt on beds of amaranth and moly,
> * * * * * *
> To hear the dewy echos calling
> From cave to cave thro' the thick-twined vine."

But this, though pleasant, is unproductive; so, by and bye, comes the hungry and hardy man of the north, and takes away both his name and country. Most of the earlier invasions and conquests arose from the necessity of the inhabitants of the more inclement regions seeking for supplies from those more favoured lands. Even a large part of early geographical discovery during the Roman Empire was due to a search after pepper, one of the most cherished condiments to aid digestion, more or less jaded with pampering and excess. Before the art of agriculture was generally understood, the men of colder and more inclement regions had either to gain a precarious livelihood by the chase or to make periodical raids upon their more favoured neighbours, and levy toll upon their more ample supplies.

The question has been much discussed as to what the original food of man was, and some people have made it a subject of excited contention. Arguments on one side or the other have been drawn from the shape of his teeth and the form of his digestive apparatus, but the most reasonable conclusion is that he is naturally a frugivorous or fruit-eating animal, like his cousins the monkeys, whom he still so much resembles. This forms a further argument in favour of his being originated in warm regions where fruits of all kinds were plentiful. But when the inevitable migration came, of which we have already spoken, what was the unfortunate man to do? A meal of wheat (a tropical plant originally), millet or maize, plantains, melons, guavas and mangoes, cocoa-nuts or jack fruit, might be all very well, but when he became reduced to beech-mast and acorns, and such tough roots as could be gathered in colder and temperate regions, he must soon have found it necessary to modify his frugivorous tendencies. Whether this change took place before or after his development out of the simian stage, that is, whether he was an anthropoid simian, or a simian man, we are not in a position to say—some are inclined to think that it was an advance made in consequence of his increase of intelligence, others that the intellectual improvement followed on the change of food. Whichever may have been the truth, it is noticeable that similar changes are found to take place in the habits of animals, even in the present day. There are flesh eating and fruit eating bears, flesh eating and fruit eating bats; whilst the practice seems to alternate even with animals of the same genus, species or individual. Polar bears, which are flesh eating generally, are sometimes driven to eat grass, which must be but unsatisfactory food to them, but the fact is proved by their stomachs being found full of it. In an ingenious paper, read at the late meeting of the British Association at Southampton, Mr. W. P. Duncan discussed the conditions under which the quadrumana, or apes, were gradually pushed southward on our globe by the increasing cold, and he suggested that the geographical distribution of land and water must have prevented some of them from reaching the regions which are now tropical, and where apes flourish in the present day. As the cold increased and fruit supplies diminished, the apes must have died off, unless they were able to find some other source of food,—and the author suggested that this they probably found in the shell-fish on the sea shore, and perhaps occasionally in the flesh of some stranded whale or other cetacean. Carnivorous monkeys are not a usual thing, but it was very curious that this suggestion, advanced on theoretical grounds, was confirmed by the personal testimony of a gentleman present, who told the meeting that he had been himself witness to the fact that, on an island he visited, the monkeys came down to the shore and gathered shell-fish and eat them,—driven to do this in all probability from a deficiency of fruits in the island.

To some extent we may thus explain the origin of cannibalism, which has prevailed more or less in all parts of the world,—for even in our own islands bones have been found which bear evidence of having been those of human beings who had been devoured by their fellow men. Such at least is the opinion of competent archæologists. There are two causes which may lead to cannibalism, viz.:—Revenge and hunger. As regards the former it must be confessed that it would be a very complete vengeance, not only to conquer your enemy, but to eat him as well, surrounding him in short both in a military and a gastronomic sense. Perhaps this may be the origin of the expression, "to have *stomach* for a fight"! Among some tribes it was a point of honour to eat your enemy if you overcame him,—and this was very rigidly carried out among the North American Indians in former times. When they proposed to make war upon another tribe they were wont to use the expression, "Let us go and eat this nation." But they drew the line at enemies, and considered it quite wrong to eat their friends, even under stress of circumstances. Indians who had eaten enemies and

sacrificial victims with not only a good conscience but lively satisfaction, were struck with horror at the acts of the Spaniards, who were driven by want to eat the dead bodies of their own countrymen.

Modern cannibalism has been most typically represented by the practice of the New Zealanders and other Polynesian islanders. Here again the habit probably arose from want of nourishing food, and particularly the absence of mammalian animals, or, indeed, large animals of any kind which might have furnished food for the hunter. Cannibalism in New Zealand is now a thing of the past, but not by any means a remote past, for there are probably men still living who have enjoyed a human steak. A brother officer of mine, who served there in the war of 1864, told me that an old chief had described to him with great gusto, mingled with a manly regret, the delights of a slice cut from the back,—the saddle in fact,—of a living captive, and eaten warm and quivering! I believe that South-Sea gourmands objected generally to Europeans, particularly Englishmen, as tasting too strongly of salt and tobacco. The general resemblance of the flesh of man to pork, however humiliating it may be, has long been noticed,—and the term, "long pig," has long been applied to it by the Fi-ji islanders. The occasional cannibalism which has arisen among shipwrecked crews and the like, need not be referred to more than to point out that man, when driven to extremity, will do pretty well anything to satisfy his appetite.

It is pretty clear that the resort to animal food, whether the result of the pressure of want from failure of vegetable products, or a mere taste and a desire for change and more appetising food, is one that took place many ages ago, probably in the earliest anthropoid if not in the latest pithecoid stage. No doubt some advantage was recognised in the more rapid digestion and the comparative ease with which the hunter or fisher could obtain food, instead of waiting for the ripening of fruits in countries which had more or less prolonged periods of cold and inclement weather. Some anatomical changes have doubtless resulted from the practice, but they are not of a sufficiently marked character to found much argument upon; all that we can say being that the digestive apparatus in man seems well adapted for digesting any food that is capable of yielding nutriment, and that even when an entire change is made in the mode of feeding the adaptability of the human system shows itself in a more or less rapid accommodation to the altered circumstances. There is one point, however, worthy of notice, and that is, whether man ought to be frugivorous or carnivorous; he begins life by taking food of animal origin, namely milk, upon which the young of all animals thrive best, whatever order they belong to. I do not think the most extreme vegetarian will propose to extend his practice to the sucking infant,—at least if he does he will prove himself an apt pupil of Mr. Malthus, and certainly check any undue increase of mankind.

But up to this time we have been talking of food and feeding without so much as proposing to define what we understand by food. Of course, a number of persons will at once say that that is clear enough,—we mean by food something to eat. That may be all very well, but there are many things we might eat that would do us little good, and many more that would do us a great deal of harm. Let us, therefore, try and define a food:—A food, then, is any substance which can be taken into the body and applied to use, either in building up or repairing the tissues and frame-work of the body itself, or in providing energy and producing animal heat, or any substance which, without performing those functions directly, controls, directs, or assists their performance. Within this wide definition it is evident that we include all the ordinary articles recognised commonly as food, and that we reject all substance recognised commonly as poisons. But it will also include such substances as *water* and *air*, both of which are essential for nutrition, but are not usually recognised as belonging to the list of food substances in the ordinary sense.

We may now inquire what are the substances that will come within our definition; what are the substances that can build up and repair our tissues; what are those that can provide us with animal heat and productive energy, and what are those that will regulate and control the work in our complex frames? Since the days of Prout, our first English organic chemist, it has been the practice to look upon *milk* as representing the food of man in its most perfect form—and subsequent investigation has gone to confirm this—with the reservation that the proportions of the constituents, although admirably adapted for the young infant, are not so well suited for the nutriment of adults. Now if we analyse milk we find that it consists of *five* kinds of substance, namely, casein, or cheese; fat, in the shape of butter; sugar, in the shape of sugar of milk; mineral matter, in the shape of a small portion of salts; and water. Now water forms about eighty-seven per cent. (or nearly nine-tenths of the whole), and the remaining thirteen per cent. is almost equally divided between the casein, butter, and milk sugar, the last slightly predominating in quantity. As we shall presently see, this relation is unsuitable for the food of adults.

When we examine the different constituents above mentioned,

we find certain broad characteristics. In the first place, they are divided into organic substances, including casein, butter, and sugar, and inorganic substances, including the salts (or ash) and water. The main difference between them is that the former, the organic, are capable of change, of being split up, rearranged, and even reduced to inorganic substances, to be burned, in short, by uniting with the oxygen of the air, and thereby producing energy, as coal does in the fire of a steam-engine.

When we carry our investigation further, we find that the organic substances may be again divided into two distinct classes, namely, that which contains nitrogen (the casein), and those which do not (the butter and sugar). On ascertaining this, we are immediately struck with the remarkable fact that all the tissues and fluids of the body, muscles (or flesh), bone, blood,—all, in short, except the fat,—contain nitrogen, and, consequently, for their building up in the young, and for their repair and renewal in the adult, nitrogen is absolutely required. We therefore reasonably infer that the nitrogenous substance is necessary for this purpose. Experiment has borne this out, for men who have been compelled to live without nitrogenous food by dire necessity, and animals on whom the experiment has been tried, have all perished sooner or later in consequence. The non-nitrogenous food, the butter and sugar, was formerly thought to be employed in providing, by its combustion or union with oxygen, the animal heat necessary for the body. This was the doctrine taught by Prout and Liebig; and, in the main, it was not incorrect, but it was distinctly imperfect, an imperfection which it owed, however, to the imperfections of the collateral sciences of chemistry and physics on which it had to depend for guidance. This imperfection led to a curiously erroneous view of the relation between the production work of man and the food he requires. Less than 20 years ago, so late as 1865, it was taught by such experienced inquirers as Lyon Playfair and the the late G. H. Lewes, that the energy by means of which our productive work is done was derived from the disintegration of the nitrogenous tissues (the muscles, in fact) which are actively engaged in the work itself. It was supposed that it would be possible to measure the amount of work done by the excretion of nitrogen during its performance.

This theory was far from satisfying scientific inquirers, who saw grave reason to doubt it, and shortly after the time I have referred to, the observations of Fick and Wislicenus during an ascent of the Swiss mountains sounded the first note of objection. These were followed by the remarkable inquiries of Pettenkofer and Voit in Munich, and Edward Smith in England,

and by the careful experiments of my illustrious predecessor, Dr. Parkes, which quite established the facts of the other observers; indeed, they showed that, so long as work was carried on at a reasonable rate, not only was no nitrogen excreted above the normal amount, but that it was rather retained in the system, being utilised in increasing the size of the organs thrown into action. Therefore, that particular view of the origin of energy had to be abandoned, but in the course of the inquiry other pieces of valuable information were obtained. For instance, it was found that one of the functions of nitrogenous food was to control and regulate the use of oxygen for burning up the non-nitrogenous food, and that if an insufficient amount of the nitrogenous food were given the burning or oxidation was diminished, and if too great an addition of fat and sugar or starch took place without increasing the nitrogenous food, the same result was obtained. This also threw a new light on the question of corpulence, which is with many people a truly vital one. Many of you may remember the history of Mr. Banting, the well-known undertaker of St. James-street, London, who had the misfortune to weigh 300lbs., or more than 21 stone, and who could only go downstairs backwards. He took the advice of his doctor, Mr. Harvey, and confined himself to a diet which consisted chiefly of nitrogenous food, such as meat, game, &c., little or no starch or sugar, except in the form of biscuit or toast, a very small amount of fat, and any wine or spirit that contained no sugar. The result was that he reduced himself to moderate dimensions, and he afterwards wrote a pamphlet in which he quaintly described his obesity as a *parasite*. This pamphlet created quite a flutter among corpulent persons, and the author's name was quickly turned into a present participle, and the verb "to bant," added to our receptive language. In many cases the results of "banting" were successful, in others they lead to serious consequences, and in some cases people imagined they were fully carrying out the system recommended if they *added* all that Mr. Banting eat and drank to their habitual diet.

Now the manner in which this kind of diet operated in reducing fat was two-fold; *first*, it cut off the main sources of extraneous fat, that is, the non-nitrogenous food, such as starch and sugar, as well as fat itself, and, *second*, it increased the oxidation of existing fat by the increased amount of nitrogenous matter, according to the results obtained by Pettenkofer and Voit. The danger that might arise would be that if the principle were carried too far, especially in persons with any hereditary tendency, gout and, perhaps, other serious diseases might be favoured. Reckless and indiscriminate experimenting on one's person is, therefore, dangerous; and this applies to many other things as well as diet.

When nitrogenous substances are used in the body, they are, of course, broken up and oxidised, or perhaps we ought to say more accurately, they take the place of the tissues of the body which wear away, and are carried off by oxidation and other chemical changes. Now, modern science tells us that such changes are accompanied with manifestations of energy in some form or other, most frequently in that of heat, and we must look therefore upon nitrogenous food as contributing to the energy of the body in addition to its other functions. But it would not do to depend upon this alone, for in order to obtain enough of energy we should have to take so large a quantity, that the body would be poisoned with excess of nitrogen. There is one other function that it seems to perform, and that is, in some circumstances to change into fat, which is useful in the system. This, however, is not its usual direction, and it is not to be depended upon.

What are the substances which we may class as nitrogenous? In the first place, we have the typical example of the purest form in *albumin*, or white of egg; and from this the name is now given to the class of *albuminates*. The animal albuminates are: Albumin from eggs, fibrine from muscles or flesh, myosin or syntonin, also from animal tissues, casein (or cheesy matter) from milk, and the nitrogenous substances from blood. In the vegetable kingdom, we have gluten, or vegetable fibrine, which is the nourishing constituent of wheat, barley, oats, &c.; and legumin, or vegetable casein, which is the peculiar substance found in peas and beans. All these substances resemble each other very much in composition, each containing about 16 per cent. of nitrogen, and the proportion of nitrogen to carbon being about 2 to 7. There are other substances than those named, but their quantities and importance are insignificant. All can nourish the human body, but the degrees of digestibility vary in the forms in which we meet them. Other nitrogenous substances are also met with, which are, however, only partially nourishing and require to be taken under peculiar conditions; of these the chief representative is gelatin, which is obtained from bones and other parts of animals, and the purest example of which is met with in isinglass, got from the swimming bladder of the sturgeon. Here we have too much nitrogen, relatively, the proportion being at 2 to $5\frac{1}{2}$ of carbon, or as 4 to 11, whereas, in the albuminates proper, it is 4 to 14.

The other organic constituents—viz., the fats, and the starches and sugars—contain no nitrogen, and were at one time thought to be concerned only in producing animal heat. We now know, thanks to the labours of Joule, Lyon Playfair, Clausius, Tyndall, Helmholz, &c., that heat itself is a mode of motion, a form of convertible energy, which can be made to do useful or productive work and be expressed in terms of actual work done. The first to accomplish this important result was Dr. Joule, of Manchester, who, in conjunction with Dr. Lyon Playfair, first established what is known as the mechanical equivalent of heat. Practically, the fact was known long before, for the whole plan of the steam-engine depended upon the principle; but, like many familiar things, the exact bearing of what was seen every day was not fully recognised. Many years before, Count Rumford had caused water to boil by blows of a hammer, thus converting visible work into heat in precisely the same way as the axle-boxes of a railway train take fire when not sufficiently greased. When Joule and Playfair proved the converse of the proposition, that heat could be converted into a definite quantity of useful work, their mutual relations were completely established. They showed that heat, sufficient to raise the temperature of 1lb. of water 1° of Fahrenheit, was equal to work which raised 772lbs. weight one foot high; or, as it is generally expressed, equal to 772 foot-pounds. This is known as the English heat unit; but it is more usual, in scientific writings, to refer to the French or metrical heat unit, which is reckoned by the quantity of heat required to raise one cubic centimetre of water (about quarter of a teaspoonful) through 1° of centigrade (1°·8 Fahrenheit), and this is equal to work which raises 424 grammes weight (about 15 ounces avoirdupois) through 1 metre in height ($3\frac{1}{3}$ft.). An English heat-unit is thus equal to about 251 French or metrical units. When we come to deal with high numbers, it is convenient to have larger units of expression, and accordingly we often speak of foot-tons instead of foot-pounds, meaning the energy necessary to raise a ton through 1 foot. An English heat-unit is accordingly equal to about $\frac{1}{3}$ of a foot-ton.

Having these starting points, it is easy now to compare the work done by a man with the potential energy of the food he consumes. By potential energy, we mean the amount of energy which it is possible to obtain by oxidising or burning the material. Thus, if we take an ounce of white sugar and burn it thoroughly, we get, as a result, carbonic acid and water, beyond which no further oxidation can take place. And if we make arrangements to save all the heat and make it heat a given quantity of water, we find that its burning yields about 370 English heat units, which are equal, expressed in terms of work to 128 foot tons, or about $\frac{1}{10}$ of a horse power. In a similar way we know that an ounce of perfectly dry (water-free) albuminate

yields about 173 foot tons, and an ounce of perfectly dry fat 378. I have already said that modern experiment showed that all our energy was derived from that of food, and, in particular, from the non-nitrogenous part of it, that is, the fat, starch, and sugar. Let us now inquire if those substances can replace each other partially or completely.

First, with regard to fat. There are various kinds of fat, such as butter, lard, oil, etc., and they have certain variations of composition and degrees of digestibility. But they all agree in an absence of nitrogen, the presence of a large quantity of oxidisable carbon, and also of a certain amount of oxidisable hydrogen. Fat enters into all diets and is eagerly sought for in all climates. It is most largely consumed in the Arctic regions, but the inhabitant of tropical Africa eats his palm oil, and the inhabitant of tropical India his ghee with great satisfaction. Fat is particularly required when considerable fatigue has to be undergone, and whenever exertion is increased to any material degree fat must be increased also. There is, however, a limit to the power of assimilation of fat, for after a certain point it is no longer received by the system, but passes from it unchanged. It provides a large amount of potential energy in a small bulk, one part being equal to two and a half parts of sugar. The other group of non-nitrogenous substances consists of the sugars and starches, represented by ordinary cane-sugar, milk-sugar, grape-sugar, and fruit-sugar; also, by honey and other sweet substances. The starches form the great bulk of the solid matter of wheat, barley, rice, potatoes, and the like. This group consists of substances quite free from nitrogen, and consisting entirely of carbon and the elements of water. The carbon is thus the only source of energy, for there is no unoxidised hydrogen; the group is generally spoken as the carbo-hydrates. They always form the greatest bulk of all diets, except those of the arctic peoples, whose geographical position puts most cereals and other vegetable food out of the question. We do not yet know what are the relative advantages of starch and sugar, or why one should be preferred to the other. All starch must be converted into a form of sugar before digestion is possible, and this is accomplished by the saliva; hence, the fatal error of giving starchy food to young infants before they have cut their teeth, and are provided with salivary apparatus to deal with it. An immense amount of fatal illness may be traced to this practice. On the other hand, the not very pleasant looking practice of mothers chewing bread and other food before putting it into the baby's mouth is really a salutary and scientific process, as doing for the child what it could not do for itself, if it must have such food.

But in spite of the necessity of this double digestion for starch, it is still preferred as food for adults to sugar, a much smaller quantity of the latter sufficing and an excess rapidly palling. The function of the carbo-hydrates appears to be to produce energy by their oxidations, either for use as animal heat or for conversion into useful work. It would also appear that by their deoxidation they can be converted into fat, and are, in fact, the main sources of fat in the animal body. Similar, however, as the functions of fat, starch, and sugar are, we do not find it possible to replace them by each other indefinitely,—each has some special advantage which has not yet been fully investigated.

There is another class of substances which are usually included in the carbo-hydrates, viz:—the vegetable acids, such as acetic acid, the acid of vinegar, citric acid, the acid of lemons, malic acid, the acid of apples, tartaric acid, the acid of grapes, and the like. These are concerned in preserving a healthy condition of the blood, and preventing the disease known as scurvy, of which I shall say a few words later on.

There still remains the class of salts or mineral matters consisting of those portions of food which cannot be destroyed by fire, and remain as ash, and of the common salt which we, most of us, if not all, add to our food. The chief constituents of this class are sodium chloride, or common salt, potassium chloride, and phosphates and sulphates of lime and magnesia and a little iron. These are just as essential as the articles of diet; the chlorides are necessary in order to yield hydrochloric acid for digestion, and the phosphates of lime and magnesia are required for many of the tissues, but especially to keep up the bony skeleton or framework of the body. If they are omitted from the food the unfortunate victim becomes listless, weak, and ultimately succumbs, and if a change in the system should occur, as sometimes takes place, when the body cannot assimilate these substances a terrible state of things results; the bones soften and give way, the whole countenance alters from the flattening of the bones of the face and head, and the patient dies sometimes from the mere pressure of the atmosphere, the soft and placid condition to which he is reduced giving no point of resistance from which the respiratory muscles can act.

The nutrition of man is best maintained when he is provided with a due admixture of all the four classes of aliment which we have mentioned, and not only that, but he is also better off if he has a variety of each class. Thus he may and ought to have albumin, fibrin, glutin, and casein among the albuminates, or at least two of them: butter and lard, or suet, or oil among the fats; starch of wheat, potato, rice, peas, &c., and cane-sugar and milk-sugar among the carbo-hydrates. The salts cannot be replaced, so far as we know. Life may be maintained in fair vigour for some time on albuminates only, but this is done at the expense of the fatty tissues, especially the fat of the body, and the end must soon come: with fat and carbo-hydrates alone vigour may also be maintained for some time, at the expense of the nitrogenous tissues, but the limit is a near one. In either of those cases we suppose sufficient water and salts to be provided.

We must now inquire into the quantities of food necessary; and this necessitates a little consideration of the way in which the work of the body is carried on. We must look upon the human body exactly as a machine: like any engine with which we are all so familiar. A certain amount of work requires to be done, say a certain number of miles of distance to be traversed, we know that to do this a certain number of pounds, or hundredweights or tons of coal must be put into the fire of the boiler in order to furnish the requisite amount of energy through the medium of steam. This amount of fuel must bear a certain proportion to the work, and also to the velocity with which it is done, so both quantity and time have to be accounted for. But there is this remarkable difference between our body and a mechanical engine that when the latter is at rest there need be no expenditure of fuel in any way, and if it does get out of order its work must be suspended in order to repair it; but in the human body we have a continual wearing away of the machinery, and an equally constant repair going on, without necessarily arresting the useful work, and while the body is at rest there must be a certain amount of expenditure to keep it together at all, which expenditure is manifested chiefly as animal heat. We have thus to consider two directions which the potential energy of the fuel of the body, that is, the food, may take; one, the more important and the one involving the largest expenditure, which has to do with the very existence of the body itself, and the other, the useful or productive work which the body can do. Every engineer knows only too well that he can never get back as useful work anything like the amount of energy which he puts in as coal into his engine, and he also knows that the apparent loss is greatly increased with increased velocity of working, in something like the cube of the rate of work. It is exactly the same in the case of man's body, for, even after so much provision has been made for animal heat and the internal work of our frame, we cannot get more than one-fifth of the additional potential energy supplied in food as really visible and useful work. When we increase the velocity of the work the proportionate amount diminishes still more, although the actual ratio is still somewhat obscure.

In speaking of quantities of food, it is necessary to explain that we must consider primarily the amount of water-free constituents. Every article that we eat, with the exception, perhaps, of perfectly dry crystallised sugar, contains some water, that is, water actually in the state of moisture which can be dried off by means of heat, without breaking up and destroying the essential composition of the article in question. The amount of water, of course, varies very much, the largest amount being found in succulent vegetables, and the smallest in flour, biscuit, butter, sugar, &c. In every pound of bread we get about *ten* ounces of solid matter and *six* ounces of water; in every pound of butcher's meat only four ounces of solids and twelve ounces of water; the same in potatoes; whilst in cabbage and such like vegetables we get only two ounces of solids to fourteen of water. In fact, in such vegetables there is more water than in good milk that has not had any clandestine dealings with "Simpson," the commercial euphemism for water. Taking the general average of diet, rather more than half (60 per cent., in fact), of what we call solid food, consists of water, and, therefore, in calculating a diet out carefully, we must have some knowledge of the composition of the articles and the amount of water each contains. When, therefore, we speak of so much albuminate, fats, carbo-hydrate, and so on, we speak of those constituents as theoretically free from water, and in order to arrive at the gross weight of food in its ordinary condition we must add once-and-a-half more weight for the water that would be contained in it. Thus: if we decide that a man must have 20 ounces ($1\frac{1}{4}$lb.) of water-free food daily, we know that we must add as much as 30 ounces more for the weight of water that would be found naturally in the food, so that the total weight of his rations would be 50 ounces or rather more than 3 lbs., only $1\frac{1}{4}$ lb. of which would be really solid.

Let us now inquire what quantity of the water-free solids is necessary. Lyon Playfair has carefully calculated the amount that would be sufficient to keep a man of average weight alive in absolute repose, the total amount being 15 ounces, representing about $2\frac{1}{4}$lbs of ordinary food. In a state of rest, that is, not absolute repose, but using no active exertion, 16 ounces are required, representing about $2\frac{1}{2}$lbs of ordinary food. Of this water-free food $2\frac{1}{2}$ ounces are albuminates, 1 ounce fat, 12 ounces carbo-hydrates, and $\frac{1}{2}$ ounce salts. This is found to be necessary to keep up the internal work of the body, such as the beating of the heart, the breathing and the various chemical changes that go on, and to supply animal heat. In short a man requires about $\frac{1}{150}$ of his weight in water-free food, or about $\frac{1}{60}$ of ordinary food every day, in order to keep alive, and not lose weight,—provided he is not called upon for active work. Some may be inclined to remark upon this, that cases are known where men have lived for a long time on much less, and other instances, more or less authentic, where people have gone on for long periods on nothing at all. We have the celebrated case of Dr. Tanner, who professed to live for 40 days without anything but water, whereas, according to Playfair's calculation, he ought to have consumed about 100lbs. of ordinary food to keep himself alive. It is difficult to discuss a case which has not been watched with scientific precision, but we have facts independently, which show that men can under special conditions, live a long time on very small quantities of food, not certainly without losing weight, but still without succumbing altogether. One essential condition is a warm temperature, or at least protection against the radiation of heat from the body. We must, however, bear in mind, that such cases, if they are authenticated, are the exception and not the rule, and in laying down laws for general guidance exceptions cannot be regarded.

There are two or three ways in which we may approach the question, besides that of direct experiment. For instance, when the chemical changes go on in the body, the carbon is converted into carbonic acid, the greater part of which is given off from the lungs, just as smoke, &c., are given off from the chimney of a furnace. Now it has been ascertained that in a state of rest a man of 150lbs. weight (10 stone 10lbs.) gives off about $15\frac{1}{4}$ cubic feet of carbonic acid every 24 hours. Now each cubic foot of carbonic acid is evidence of the expenditure of 160 foot tons of energy, and $15\frac{1}{4}$ multiplied by 160 gives us 2440 foot tons total energy per diem. Again, if we examine the temperature of the human body we find that it is normally 98°·4 Fahrenheit, whereas the average of the air is not above 50° F., indeed, here in Newcastle it is lower than that, about 48° I think. Let us take the difference, however, at 48°F., and suppose that the 150lbs. of man's body absorbs heat in the same ratio as water, and it actually does contain 90lbs. of water; we shall find $150 \times 48 \times 775 \div 2240 = 2481$ foot tons of energy expended, a difference of only 41 foot tons from the calculation by the carbonic acid, or less than 2 per cent. If now we turn to the food calculated by Playfair we find the following amounts of potential energy—

Albuminates, $2{\cdot}5 \times 173 = 432$, Fat $1 \times 378 = 378$, and Carbo-hydates, $12 \times 138 = 1656$, total 2466 foot tons.

The correspondence between these three numbers is remarkable, and, even allowing for error, it goes far to prove the accuracy of Playfair's induction.

But the end of man is not to lead a merely vegetative life:

> "What is a man,
> If his chief good, and market of his time,
> Be but to sleep and feed? A beast, no more."

He must be up and doing and produce some actually visible work. This, however, he can only do if the necessary energy is supplied to him through food. Let us first consider what amount a man usually does. Suppose a man wields a hammer of 14lbs. weight, and that at each stroke he raises it 4ft., then each stroke is equal to 56 foot pounds, or $\frac{1}{40}$ of a foot ton: therefore, 40 such strokes will equal 1 foot ton. A fair day's work will be about 12,000 strokes, or 300 foot tons. But work is frequently greater than this: a man has been known to raise a weight of 90lbs. a foot and a half, 12,000 times in the 24 hours: this is equal to 723 foot tons. Usually, however, for average men, the maximum is 600 foot tons, and even that cannot be carried on for more than a limited period. The estimate is generally as follows:—

Light work	150 to 200	foot tons per day.	
Average "	300 " 350	"	"
Hard "	450 " 500	"	"
Laborious "	500 " 600	"	"

What such work means will, perhaps, be better understood by stating the distance it corresponds to in walking. It has been ascertained (especially by the Rev. Dr. S. Haughton, of Dublin) that ordinary walking, at about three miles an hour, is equal to about $\frac{1}{20}$th of the work done against gravity in raising up the body perpendicularly; say, mounting a perpendicular ladder. Therefore, a man who weighs 160lbs. (11st. 6lbs.) in his clothes, walking on level ground, does, for every mile of distance, nearly 19 foot-tons; hence, a light day's work would be from 8 to 10 miles, an average day's work from 16 to 18, a hard day's work from 24 to 27 miles, and a laborious day's work from 27 to 32 miles. Few men would, I fancy, care to walk 30 miles a day for six days a week continuously. Of course, if additional weight is carried, this must be taken into account.

Again, if the rate or velocity is increased, we must account for that also; for every mile of additional velocity per hour the resistance is increased by about one-fourth, so that the work per mile done is increased in this proportion, four miles in one hour being equal to five miles done in an hour and forty minutes. Long-continued exertion, even at moderate rates, tell also severely. The extraordinary feats performed by professional pedestrians, such as Weston, Gale, O'Leary, and others, are very severe, and must tell seriously on the constitution. I have calculated out some of the work done on these occasions. When Weston and O'Leary walked six days against each other, the former did about 1750 and the latter over 1900 foot-tons every 24 hours; Gale, who walked 1500 miles in 1000 hours performed an enormous feat of endurance, amounting to 560 foot-tons per diem continuously for six weeks. But the work per man of the sledge parties in Nares' arctic expedition was even greater and done under the most adverse conditions. It is quite clear that this energy expended must come from somewhere, and it ought properly to come from the food; if it does not, then it comes from the framework of the body itself. Helmholz has shown that, for ordinary work, an amount of food must be given (over and above that for existence) which is equal to *five* times the amount of potential energy expended in useful work. Thus, for a day's work of 300 foot-tons, an addition to subsistence-diet must be made equal to 1500 foot-tons. If the work is harder, the proportion must be still greater; so that, for a hard day's work of 450 foot-tons, we must give the equivalent of nearly six times, and, for 600 foot-tons, seven times, the visible energy expended.

As a general rule for average work, we obtain about $\frac{1}{14}$ to $\frac{1}{13}$ of the total energy, given in the shape of food, returned as useful work. The standard diet for average work is generally accepted as the following:—

Albuminates	4·6 ounces.
Fat	3·0 "
Carbo-hydrates	14·3 "
Salts	1·1 "
Total	23 ounces water-free.

This argues about 3½lbs. of ordinary so-called solid food, and would yield 3878 foot-tons of energy, which gives 1438 for the useful work, slightly under the required amount. Accordingly this diet would be improved by a slight increase in the fat, and this increase is actually made in the diet proposed by Pettenkofer and Voit. There is another thing that must also be remembered, and that is, that all the material is not thoroughly used up, that some portions escape oxidation, like the cinders of a coal fire, so that a margin of ten per cent. may fairly be allowed to make up for this. When the work is increased so must the food be, chiefly in the direction of albuminates and fat. Sometimes the result is stated as nitrogen and carbon, in the proportion of 300 grains of nitrogen and nearly 5000 of carbon: it is safe to allow one additional grain of nitrogen and sixteen of carbon for every additional foot-ton of work. By carefully apportioning food to work it will always be easy to get the best results; but if this be neglected failure and disappointment result. It was to neglect of this fact that we owed the deaths of so many victims in the great famine in Madras a few years ago; and the mistake is still made in the dieting of our soldiers, our prisoners, and others in public institutions. A glance at the diets of different armies will show at once their deficiencies compared with the standard diet. They are all deficient in albuminates and fat, and have an excess of carbo-hydrates.

DIETS OF EUROPEAN ARMIES.

	English.	French.	Prussian.	Austrian.	Standard.
Albuminates	3·86	4·33	4·02	3·73	4·6
Fat	1·30	1·27	1·09	1·64	3·0
Starches	17·43	18·04	19·62	17·00	14·3
Salts.................	·81	1·00	1·50	1·00	1·1
	23·40	24·64	26·23	23·37	23·0

It is curious to observe the marked deficiency in fat, and nearly in the same proportion in all the armies. In our country the soldier often supplements his somewhat deficient diet from his own pay, but abroad the French or German soldier cannot do much in that way, his pay being much smaller. The Austrian soldier has, however, some additions, such as garlic, onions, vinegar, &c. When war breaks out a very material change is made, and an increase provided commensurate with the increased exertion demanded.

Much controversy has taken place on the subject of vegetarianism, and almost as much heat has been imported into it as in a religious discussion, the *odium theologicum* having its counterpart in the *odium dieteticum*. We have seen that the vegetable kingdom furnishes all the necessary constituents for a nourishing diet, but the question is chiefly one of habit and digestibility. The most nourishing vegetable matter is peas or beans, which, weight for weight contain more nitrogen than meat. But they soon pall upon the appetite and produce indigestion. The Germans found this with their celebrated pea-sausage in their late campaigns. Wheat, oatmeal, and maize are all nutritious, but they contain too much starch to provide a thoroughly good diet alone. But the great difficulty of a vegetable diet in a cold climate is the want of fat; in warm countries oil easily supplies this, but in cold countries there is hardly any vegetable which yields fat in any quantity, except rape-seed, linseed, mustard-seed, sun-flower seed, and the like, and none of these oils are very attractive as articles of diet. As for the people who call themselves vegetarians, and yet make free use of milk, eggs, cheese, and butter, I have nothing to say, except that they are sailing under false colours; they are not vegetarians, but mere abstainers from flesh meat.

The question of dried, concentrated, and preserved food is one of great importance. Some mistakes have arisen with respect to these, people occasionally imagining that a day's ration may be concentrated to the size of a lozenge and the like. Now this is absurd: we can only concentrate food by driving out the water, and we have already seen that an ordinary day's ration must consist of at least 23 ounces of water-free food, so that about 1½lbs. is the absolute limit of concentration or drying. Even this can hardly be reached, for if we dry up food to this extreme extent, it becomes quite indigestible, and consequently, not only useless but hurtful. The most concentrated food known is probably pemmican, the food so much used by Arctic voyagers; and even this contains about 7 per cent of water. Preserved food, on the other hand, is food preserved from decay in its natural state, without any loss of water. The whole system of preserving and keeping food is now being brought to great perfection, and the improvements that are daily made will prove the greatest boon to all classes, by enabling us to store food that would otherwise be wasted, and generally by cheapening, and making nutritious and palatable, the diet of the poorer classes.

No lecture on diet would be complete without a reference to the vexed question of alcohol. I am no teetotal advocate, and I repudiate the rubbish too often spouted from teetotal platforms, talk that is, perhaps, inseparable from the advocacy of a cause that imports a good deal of enthusiasm. I am at one, however, in recognising the evils of excess, and would gladly hail their diminution. But I believe that alcohol properly used may be a comfort and a blessing, just as I know that improperly used it becomes a bane and a curse. But we are now concerned with it as an article of diet in relation to useful work, and it may be well to call attention markedly to the fact that its use in this way is very limited. The experiments of the late Dr. Parkes, made in our laboratory at Netley, were conclusive on the point, that beyond an amount that would be represented by about one-and-a-half to two pints of beer, alcohol no longer provided any convertible energy, and that therefore to take it in the belief that it did is an error. It may give a momentary stimulus in considerable doses, but this is invariably followed by a corresponding depression, and it is a maxim now generally followed, especially on service, never to give it before or during work. There are, of course, some people who are better without it altogether, and to all moderation ought to be commended, if not enjoined.

There are other beverages which are much more useful than the alcoholic, as restoratives and for support in fatigue. Tea and coffee are particularly good, although their use is sometimes carried to excess, as, for instance, in the ridiculous practice of afternoon tea, which has become so fashionable of late years. Another excellent restorative is a weak solution of Liebig's extract of meat, which has a remarkable power of removing fatigue. Perhaps one of the most useful and most easily obtainable is weak oatmeal gruel, either hot or cold, the value of which has often been found during heavy and continuous work, by railway labourers and others. Particular attention was called to this by the late Dr. Parkes. With regard to tobacco, it also has some value in lessening fatigue in those who are able to take it, but it may easily be carried to excess. Of it we may say, as of alcohol, that in moderation it seems harmless, and even useful to some extent, but, in excess, it is rank poison.

There is one other point which I must refer to, and which is especially interesting to a great seaport like this. This is the question of scurvy, a question of vital importance to a maritime nation. When the human body is in a state of health the blood is alkaline, and the juices of the flesh are acid. Under these circumstances galvanic currents are the normal result. Whether these be necessary or not it is quite certain that this relative condition is essential for health. Under certain circumstances this alkalinity of the blood becomes diminished, and then a terrible train of symptoms sets in; the blood becomes very fluid, and loses the power of coagulating: it exudes through the walls of the vessels and appears in red and purple patches on the limbs, the gums become spongy and bleed, and the teeth loosen and drop out, the eyesight is impaired, diarrhœa sets in, and if crowding and starvation are added, typhus shows itself with fatal results. Any one who has seen such a stare of things can never forget it.

I have a most vivid recollection of the first winter of our Crimean Campaign, which I passed in the hospitals at Scutari, where scurvy and typhus carried off both officers and men. Scurvy was the dreaded scourge of our fleets in the last century, and again and again went nigh to compromising our position

as a naval power; the Channel Fleet used sometimes to return hopelessly crippled with 10,000 sick and useless on board. Although in the work of Woodward, in the 17th Century, the value of acid fruits were pointed out, and although more than a century later Captain Cook had practically proved their efficacy, it was not till 1796 that the authorities would listen to the remonstrances of the medical officers of the fleet and issue lime-juice. But when it was done the effect was magical; scurvy disappeared like a troubled dream, and the gastly demon of former days was most successfully exorcised.

From that time down to the present, the issue of lime-juice has been compulsory on board our fleet, within certain fixed periods after the issue of fresh meat and vegetables has ceased. It is also a regular part of the equipment of any land expedition. The consequence has been that scurvy has been unknown in our fleet; except, on Arctic expeditions and such exceptional occasions, for all this century. But it still made its appearance from time to time among our merchant shipping. An act was passed, however, in 1867, called the Merchant Shipping Act, which enjoined the issue of lime-juice to ship's crews after they had been a certain time on salt provisions. This Act was followed by amended improvement, for, whereas in 1867 and 1868, there were respectively 88 and 90 outbreaks of scurvy among British ships, there were only 22 in 1869, and 19 in 1873.

A paper lately issued by Mr. Thomas Gray, of the Board of Trade, discloses the regrettable fact that since 1873 there has been a serious falling off, the outbreaks of scurvy having again increased until they reached 99 in 1881. This, Mr. Gray seems to think, is due to a neglect of varied food scales; but it may also very probably have arisen from the neglect of the regulation about lime-juice, either as to issue or quality, or both. But it is also a fact of very great importance that mere monotony of diet has a most serious effect upon health; variety of food is not merely a pandering to gourmandism or greed, but a real sanitary benefit, aiding digestion and assimilation. As a habit there is too much neglect of green vegetable food in England, particularly in the more southern parts, where bacon and beans form a staple part of diet. In the north, and still more in Scotland, vegetables enter much more largely into the daily food, and no more wholesome and anti-scorbutic food could be found than Scotch broth, or, still better, hotchpotch, the very prince and king of soups. It is a curious fact that this culinary defect has clung to the English name for centuries.

It is on record that, at the siege of Breda, in the seventeenth century, where the English were engaged alongside French and other troops, they (the English) suffered from scurvy and dysentery much more seriously than the others, due, it was believed, to their neglect of vegetable food and to their drinking brandy or other spirits, whilst their allies drank red acid wine. Many of the earlier campaigns in France were marked by the same thing; and this was, probably, one of the causes of the sickness of Henry the Fifth's army in the campaign of Agincourt. Again, the sailors of the French and American fleets have never suffered from scurvy to the same extent as ours; and it was not till sixty years after the introduction of lime-juice into our fleet that it was thought necessary to make similar regulations in the fleets of other countries. The Americans used to taunt our men with this, and call them "lime-juicers."

Now the reason of all this has been that the diet has been much more varied and more thoroughly antiscorbutic in foreign vessels, particularly in their merchant ships. The actual amount of nutriment has been as large in our ships, but it has been less varied and less judiciously arranged. Our Board of Trade has nothing to do with the food scales of ships, but Mr. Gray hints that the legislature will have to interfere unless ship-owners look to it themselves. The ease with which preserved foods of all kinds can be obtained and carried now removes the last shadow of an excuse for backwardness in this matter, and in particular the provision of a large supply of potatoes, both fresh and dried, ought to be an unceasing care; this is done on board American ships, and to this is doubtless owing in a great part the healthiness of their crews. Scurvy in the present day is a disgrace to ship-owners and masters, and if public opinion is insufficient to protect the seaman the legislature will undoubtedly step in and do so.

And now, ladies and gentlemen, let me close this, I fear, rather prosy lecture, by pointing out that the study of this common-place matter of eating and drinking opens out to us the conception of the grand unity of nature; since we see that the body of man differs in no way essentially from other natural combinations, but is subject to the same universal physical laws, in which there is no blindness, no variableness, no mere chance, and disobedience of which is followed as surely by retribution as even the keenest eschatologist might desire.

THE NEXT TO GODLINESS.

AN ADDRESS TO THE WORKING CLASSES

By Benjamin Ward Richardson, M.D., F.R.S.

J. COWEN, M.P., IN THE CHAIR.

When the man of genius who represents the city of Newcastle ceased to speak, I was reminded of the remark which was applied by Ben Jonson to Lord Bacon, namely that when Lord Bacon spoke there was only one anxiety amongst the people who were present, and that was that he would too soon stop. Now Mr. Cowen has ceased, and it is my duty to take up the discourse. I have been invited to give a lecture to Newcastle working men, and I am going to do so, in that sense, strictly. It is not uncommon for public men in speaking to working men and women of the country to begin by saying insinuatingly and sweetly that they, the speakers, are also working men. The working listeners listen, and sometimes out of their politeness and good humour applaud the remark, while at the same time they know perfectly well what it means. I shall not follow that course, but shall define what I mean as the working classes to be the men and women who, in the fields, the workshops, and the factories, labour with their hands and receive wages for their labour, an audience, if one could reach the whole of it, the greatest, numerically, attainable.

The national family of England and Wales, reckoned when it was about 25 millions, stood nearly as follows:—Eight millions were children, six were women and others of the household, domestic people, making 14 together. One million was a commercial class, buyers and sellers, making 15. One million was a ne'er-do-weel class, persons in the workhouse, the prison, or asylum, 16. One million was an independent or professional class, politicians, clergymen, doctors, lawyers, soldiers, sailors, artists, or some other salaried, fee'd, or wealthy individuals who belonged to what is called the ruling body of the nation, 17. Two millions were workers on the land, 19; and six millions were workers in the shops, factories, and other centres of work,