ART. V. — *Practical Deductions from an Experimental Inquiry into the Influence of Foods.* By EDWARD SMITH, M. D., LL. B., L. R. C. P., Assistant Physician to the Hospital for Consumption, &c., Brompton.

WHILST engaged in a lengthened series of inquiries into the influence of foods over the respiration, which have been published in the Philosophical Transactions for 1859, various facts have been observed which are of interest to medical science; and, although the inquiry is a physiological one, it has afforded data calculated to direct us to practical truths.

The experiments which have hitherto been made as to the influence of individual articles of food have been almost exclusively made upon animals, with a view to determine their influence upon growth and fattening, as in those admirably conducted by Boussingault, and Messrs. Lawes and Gilbert of Harpenden; or to determine how long an animal would live upon one kind of food, as sugar for example, exclusively. A few have been made upon man,—as those of Prout on alcohols; Lehmann on tea and albumen; Vierordt on white wine; and Böcker on tea, coffee, sugar, and alcohol: but in respect of most of these it may be remarked, that the inquiries were very limited in number; were not serial, as those of Vierordt and Prout; were not made at the only period of the day when the uniform state of the functions permitted the investigator to trace the changes due to the food alone,—as those of Böcker, Vierordt, and Prout; were made with excessive quantities of the food, as when Lehmann ate thirty-six eggs, and Böcker ate large quantities of sugar repeatedly; and were not made whilst the ordinary quantity of ordinary nutriment was taken daily.

Hence much that is known is not applicable to the determination of the daily wants of the body in man; and, of the rest, much is exposed to error from the defects in the method adopted. The greater part of the knowledge which we possess, and upon which we at present rely, has been deduced from the chemical constitution of the various kinds of food, and in this respect we are chiefly indebted to Liebig, the most sagacious chemist of the day; but even chemists are not slow to admit that much of this kind of knowledge is hypothesis; which, if true, yet needs the help of additional proof, and, when admitted to the full, fails to explain the transformations which the food undergoes in the body, and the precise mode in which it nourishes the animal frame.

Under these circumstances, I think it necessary to state,

that the observations contained in the following paper are exclusively derived from my own experiments. These experiments (2000 in number), in many cases, confirm previous knowledge, by adducing proof which had not been heretofore derived from the human system, whilst in others they tend to correct error, and in many give explanations of known facts, as, for example, the inferior value of starch to wheat-flour as a nutrient, not alone (as has been hitherto supposed) because the latter only contains material to build up the tissues, but, as I have shown, because nitrogenous compounds, when present, promote the transformation of starch.

Whenever my results differ from those obtained by previous observers, I offer them with all deference, but at the same time with confidence; and refer to the fact that, up to the period of my experiments, there was neither opportunity nor method devised by which such experiments could be made in the accurate and serial manner which is now possible. I venture also to hope that, where my observations refer to and support facts which are known, they will not be deemed out of place, seeing that they are based upon new proofs of our knowledge.

As I do not propose to enter into detail with reference to the experiments, I must refer to the Philosophical Transactions for a description of the method employed and the results obtained. The aim was to determine the effect of various kinds of food (each taken alone and in a moderate quantity, and all under precisely similar circumstances) upon the respiratory function and pulsation, and also upon some other functions of the body. The effect was isolated by taking the substance when fasting, before breakfast, and in a state of perfect rest, and by repeating the experiments every twelve to fifteen minutes during its action. The persons subjected to inquiry were chiefly myself and Mr. Moul; but Professor Frankland, F.R.S., Mr. Hoffman, of Margate, and Mr. Reid, of Canterbury, all in perfect health, kindly lent their aid. The apparatus employed for the collection of the carbonic acid is described and figured in the papers above-mentioned.

Before entering upon the subject, I propose to offer a few introductory observations.

It is known that a large amount of vital action must be maintained in order to preserve life, so that in cases of starvation the sufferer does not continue to live until every vital change is progressively lowered to zero; but, on the contrary, dies whilst there is still a large amount of vital action. This is not explained even in cases of starvation by stating that the

stock of nutriment is exhausted, since it would be more rational to assume that, as the stock diminished, so would the vital actions diminish until both subside to zero, and in the present state of our knowledge we can give no other explanation than to say that it is one of the properties attaching to life. The determination of this *necessary* amount of action is therefore both interesting and practically important, since it shows to us the reason for the rapid exhaustion of the system in the absence of food. Cases have occurred in which life has been maintained for some weeks, both in health and disease, in the total absence of food, except the important one of water; but it is well known that privation of food is a most powerful and urgent agent in the hands of both the physician and the magistrate, and over both the mind and the body. In my experiments I did not feel justified in fasting longer than twenty-seven hours (or rather forty hours, with only a moderate breakfast in that period), for, had I proceeded further, I should probably have set up some action allied to disease. Two facts were noticed of interest to the physician, viz., that in this total absence of food the amount of respiratory action was still seventy-five per cent. of that which would have occurred in the twenty-four hours with food; and, second, that the respiratory function was almost absolutely uniform through all the hours of the daylight day—that is, at the periods when the variations with food are extremely great. In my case, the total quantity of carbonic acid exhaled during the twenty-four hours of fasting (the body being at rest) was nearly twenty-two ounces, containing a quantity of carbon equal to that found in twenty ounces of bread. This loss would soon exhaust whatever excess of nutritive material might have been previously found in the system, and hence the withholding of food is, as has been long known, the most natural and efficacious remedy in some forms of dyspepsia, disorders of the liver, and inflammations, and in numerous cases of threatened disease.

It has been observed in experiments on animals, that, from the moment when food was withheld, there was a gradual and progressive decline in the carbonic acid emitted until it was reduced below the amount observed in my case. In myself there was not such a progression during the period of the experiment; but, after having fasted twenty-two hours, the quantity of carbonic acid evolved was precisely that which had occurred at seven hours on the preceding day, and the total variation in the twenty-seven hours did not exceed half-a grain of carbonic acid per minute above or below the quantity re-

corded five hours after the last meal. Hence, uniformity of vital action is the most remarkable characteristic of a fast of this duration. The general effect upon the system was well marked, since the blood became unduly alkaline, as evinced by an alkaline state of the urine, and an increased degree of alkalinity of the saliva, which were noticed after twenty-five hours^a. The urine was of specific gravity 1018, and high-coloured. The pulse was very soft, and wavy or jerking, with throbbing in the head, and a most unpleasant headach at intervals, depending, doubtless, upon the feeble action of the heart and lessened quantity or changed character of the blood. There was no marked sense of craving for food or drink, but, succeeding to a feeling of great tameness, was a peculiar kind of irritability, which is the prelude to the delirium known to attend inanition, and which, as Dr. Copland has so well remarked, has been often induced by the exhausting treatment of disease. The alkaline state of the blood whilst fasting is much greater than the degree of it which follows the administration of food, and has a peculiar significance in relation to Baron Liebig's views as to the carrying powers of blood in reference to the carbonic acid, and must be attended by diminished respiratory changes. Having ascertained the fact of the increased alkalinity, I was desirous to learn if the introduction of acid, which is capable of being resolved into carbonic acid, would increase the chemical changes and diminish the alkalinity of the blood; and therefore drank six drachms of good vinegar in water; but only a slight and temporary change ensued. There was, however, a fact which is worthy of note; viz., that the unpleasant sensation in the head ceased almost instantly, and the pulse became a little quicker and sharper; but after the lapse of a few minutes the improvement subsided^b. Arrow-root gave no relief,

^a It has been objected that the state of the excretions is not sufficient evidence as to the degree of alkalinity of the blood; but I cannot think that any one who, with sufficient knowledge, reflects upon the subject, can hesitate to adopt views similar to those expressed by Liebig, both as to the constitution of the blood and the mode by which it carries on its functions through a perpetual interchange between various acids and the bases in the blood, and that he must admit there is such a correspondence between the state of the urine and other excretions with the blood, that the condition of the latter may be reasonably inferred from the former. If, for example, we find an unusual quantity of acid passing off by the urine and the perspiration, not connected with an unusual ingestion of acid, whence could it have been derived but from the blood which contained it in excess; that is to say, in greater amount than could be transformed by the aid of the alkalies then existing in the blood?

^b Although acetic acid is, as above stated, capable of being resolved into carbonic acid, it has yet the power of modifying the degree of alkalinity of the blood, for it

but rather the contrary; and the same may be said of a cup of tea; but when I sat down to dinner, and had eaten food about five minutes, the great sense of exhaustion, the distressing headach, the fluttering pulse, and the excess of alkalinity of the blood, began to pass away, and before the meal was over I was in perfect health. Hence it was again proved that physis, however well directed, is of little use to the starving man.

The other preliminary remark which I venture to offer is, that this low and uniform line, representing the respiratory changes which I have shown to occur during a lengthened fast, is precisely that to which the respiration falls at the end of the interval between meals; so that, whether with or without food, there is a tolerably uniform basal line below which the system does not pass—the elevation of the line differing at different periods of the year. Above this line there is an elevation from the influence of food—an elevation which is also tolerably uniform, and restricted to a maximum increase of from two to three grains of carbonic acid per minute. It is not the same after every kind of food, and with meals is the greatest after the breakfast and the tea. Thus there are two degrees in which food may be proved to act, both of which are distinct and well defined; viz., that which maintains the chemical changes to the minimum line, and that which raises them above it. It is, however, clear that the former does not suffice alone to maintain life, and therefore that the latter, although a temporary, is an essential action.

I shall next refer to the effects of several substances which act in one or both of the degrees now pointed out.

Pure starch as arrow-root, and fat in various forms, but chiefly at the present day as cod-oil, are extensively prescribed; the former to infants, and also to adults with an enfeebled state of the assimilative function, under the idea that it is highly nutritive and easy of digestion; and the latter, in cases of wasting and cachectic states of the system. My experiments have shown that, although they are respiratory foods, they do not excite the respiratory function; or, to speak more accurately, starch gives a very slight increase, and fat causes a decided decrease. The action does not exceed that minimum or basal line which I have just shown to be insufficient to maintain life.

must enter that fluid as free acid, and, until its transformations are completed, it will necessarily have an acid reaction. This would be exerted for a limited period only, as was shown by the effects described.

I have already stated that after a long fast, when the system must require food, arrow-root and water gave no feeling of satisfaction, but, on the contrary, a sense of sinking at the stomach and small intestines; and its effect upon the respiration was scarcely more than occurs in the entire absence of food. The pulse was reduced in frequency. Hence we find an explanation of the impropriety of attempting to feed infants on arrow-root boiled in water, under the idea that arrow-root alone is a nutritive food. It has been abundantly proved that animals cannot live on starch, and yet it is not uncommon to find mothers with deficient milk giving to their infants arrow-root, or some of the fashionable preparations of corn, which consist almost entirely of starch freed from the important nitrogenous constituents, and using water instead of cow's milk, under the impression that the latter would be too rich a food. Such a course can only lead to starvation.

But starch, apart from other substances, is not found in nature, and the result of its action is very different when it is administered in the combinations so universally provided for man, viz., in the cereals. These, whether wheat, oats, or rice, have a most powerful and enduring influence over the respiratory function—an influence extending to an increase of two grains or upwards of carbonic acid per minute, and continuing to the extent of upwards of one grain per minute for between two and three hours. With these foods, moreover, there is a complete sense of satisfaction, and it has been proved that they are capable of sustaining life. Hence the administration of wheat, flour, or bread, instead of arrow-root, where we desire to improve the nutrition, is clearly indicated. The uniformity of action of these three cereals, some of which are found in nearly all parts of the earth, and upon which the life of man universally depends, is an interesting fact, for in all essential respects their action is identical, the quantity being varied according to their relative variations in carbon and nitrogen. Rice, however, is chiefly used in hot climates, and tends more to excite pulsation; and oatmeal, which is almost exclusively employed in cold climates, appears to have the advantage of maintaining a tolerably uniform and elevated line of respiratory action for a more lengthened period than the others. Hence oatmeal is not only a good, but a cheap food, as our northern brethren know well.

There is also another fact of importance connected with the use of the cereals, viz., that however valuable more highly nitrogenous food, as beef or beef-tea, may be, they do not, when taken alone, at all equal in value wheaten bread; for, whilst

the former can at the most only sustain the waste of tissues, the latter is capable of sustaining every function of the body^a. Hence, in cases of debility, and particularly of impending exhaustion, where the system has probably for a long time experienced more waste than supply, the too frequent habit of relying upon beef-tea and wine, to the almost total exclusion of the cereals, is not defensible. In all such cases, whilst we may seek to arrest waste by any remedy which is presumed to have that power, the real supply must be derived from the cereals. No one who has, when fasting, taken even *good* beef-tea alone can have failed to notice the very insufficient sense of satisfaction which it gives, and how soon there is a feeling of sinking or malaise about the stomach and small intestines; and it may be laid down as indisputable that a food which does not give a sense of satisfaction is insufficient to support all the processes of the system. I am desirous, therefore, of affirming the importance of the use of the cereals, with or without other food, as that by which waste must be repaired in cases of prolonged exhaustion, whether with or without imminent peril. In the opinion of Dr. MacLagan, expressed in a letter with which he has kindly favoured me, the use of beef-tea, freed from albuminous compounds, is simply to lessen waste; an important influence, no doubt, but as that substance does not supply the material which is required by the system, it only delays, and does not cure the evil. The cereals have a quick as well as a powerful influence; so that within half-an-hour they cause an increase of one grain of carbonic acid per minute; and in this respect they are not exceeded by any of the substances which are true foods.

The true influence and value of potato have, I think, been often misunderstood. I find that it differs from the cereals in the lessened duration rather than in the amount of influence, for with eight ounces of good potatoes I always obtained an increase of one and a half grains of carbonic acid per minute. The effect did not usually endure longer than one and a half hours, and the subsidence of it was very rapid. When

^a If it be objected that there can be no proper comparison of beef-tea and the cereals, on the ground that the former does not possess plastic compounds, I venture to remark that it is far from being a settled question as to how far gelatinous compounds are useless in the formation of tissue, and that the well-known "Gelatine Commission" by no means settled this question. I have proved, as will be seen further on, that gelatine acts, like other nitrogenous compounds, as a respiratory excitant; and moreover, if beef-tea is properly prepared, it contains much albumen and plastic matter. If the imperfect knowledge which we at present possess is to be the standard by which all new investigations are measured, we can make no progress, and he who so uses it is an obstructor of knowledge.

conjoined with mineral matter, it has been abundantly proved to be capable of sustaining life, and hence it has not, I think, obtained that credit which is its due. There are, however, two disadvantages, in respect of one of which I think there is a common error, viz., that a large quantity must be taken in order to afford a sufficiency of nutriment for the respiratory function, and even then the quantity would be deficient in nitrogen; and in this quantity it is a much dearer article of food than the cereals. It is in this latter particular that popular error occurs, and one, moreover, which the dietaries of our prisons and work-houses show to have extended to scientific men too. To supply a given amount of carbon and nitrogen to the system, it costs two and a half times as much to obtain it from potato as from bread, and it cannot be too widely known that the cereals are not only the best but the cheapest of foods.

Milk, also a fundamental article of food, and one which enters largely into our sick dietaries, either as new milk, skimmed milk, or cream, appears to have different actions upon different individuals, if we may judge by the variety of tastes regarding it, and the ill effects which many ascribe to its use. My experiments show both that it has a powerful and enduring action, and that it differs in its physiological effects in different persons. In my own case (I am fond of milk) the effect of new milk is extremely analogous to that of the cereals, both in the extent and the duration of its action—a fact of great interest, since each is able to support life alone for very considerable periods—both being, in fact, alike the “staff of life” at different periods^a. It is also of interest to know that the action of every element of the milk, viz., the sugar, acid, casein, and cream, tends in the same direction, but that no artificial combination of these elements, and no separate element, has the full effect of the natural new milk. New milk increases both the respiration and the pulsation, and in the latter effect it does not correspond with the cereals.

Skimmed milk is held in great repute amongst the German physicians; and in Greece, Turkey, and the western United States of America, sour milk, or milk with the casein coagulated, is a most common article of food. In skimmed milk we still retain the casein, acid, and sugar, and I have proved that it produces an increase of the respiratory function to the extent of more than one grain of carbonic acid per minute. Casein alone,

^a In the higher mountainous regions of the Tyrol Switzerland, and Sweden, the mountaineers drink a gallon, or other very large quantity, of milk daily, and in the comparative absence of the cereals, this is in adult, as in infant life, their principal sustenance.

and sugar of milk alone, will each produce nearly the same effect; but lactic acid scarcely, in ordinary conditions of the system, affects the respiration. Hence, I believe the value of skimmed milk to be chiefly referable to the casein, and that not simply as a plastic material, but, as I shall presently show, from its power to increase the transformation of respiratory food, in fact, increasing the assimilation of food. On this ground only, I think, can we account for the fact to be presently noted; that the addition of one half pint of skimmed milk to the ordinary dietary of prisoners was of remarkable benefit. It is also highly probable that in states of the system in which there is an unusual tendency to an alkaline state of the blood, as, for example, in the hot season, the free use of the lactic acid in sour milk tends also largely to increase the transformation of material, and thereby to improve the assimilative function by causing a more rapid interchange of the acid and base in the blood, and the more rapid disengagement of carbonic acid. Thus, in cases in which we desire to avoid increase of pulsation, where we wish to increase the transformation of nutritive material without adding to the carbon in the system, and where we find an acid rather than an alkaline fluid to be indicated, skimmed milk, or sour milk, as the case may be, is preferable to new milk. Such, no doubt, are many cases of fevers. Cream, in days gone by, supplied the fat in sick dietaries which is now given in a more nauseous form, and in many cases with good reason, for it has a greater influence over the respiratory function than separated fats, since it retains a certain amount of acid and sugar, and it has an equal influence over pulsation.

Hence we find an explanation of the well-known fact of the great propriety of combining bread with milk in food when we desire to well nourish the system, and the proof that they are in truth the sustainers of animal existence.

I have already stated that fats do not increase the evolution of carbonic acid, but, on the contrary, that they lessen it. This is seen in both butter and olive-oil, the two kinds of oil or fat used most commonly as food; but it is most evident in cod-liver oil, the fat most commonly used in medicine. The depression is not, however, great. There is also a soothing effect when any considerable quantity is taken at once, as one ounce of butter or cod-oil alone, not very pronounced, but sufficient to be noticeable and pleasant. Fats always increase the pulsation, and in about twenty minutes cause a sense of satisfaction and of slight fullness at the heart. As fats are not transformed in the process of digestion, but pass into the lacteals in a molecular state, and are deposited in the

tissues as fat, it must be evident how advantageous a mode of administration we have in milk with its alkaline reaction, in which the oil is ready divided into molecules and associated with albuminous material ready to its use. Hence I think that new milk is a better mode of administration of fat than cream even, and much more than separated oil, provided a quantity be taken which will supply the required quantity of fat. Each pint of milk contains about three-quarters of an ounce of butter.

As fat and starch are similar aliments, and yet both seem to be necessary to the system and to be agreeable to the appetites of mankind, it is of the greatest interest to determine the mode by which they severally act, so as to ascertain the difference which must exist between them. No satisfactory explanation has been given; and, although I have ascertained several respects, both physically and physiologically, in which they differ, I feel that further observations are still necessary. With regard to the influence of temperature, I am assured by Sir James Ross that no large increase of fat is necessary to our sailors in the Arctic regions; and by Professor Sandhal, of Sweden, that the peasantry of Lapland do not take food materially differing from that of our own country. Moreover, in hot climates, as in Italy and China, fat is used largely with the starch, and hence I think that in practice there is less difference amongst mankind than is commonly supposed. We must also recollect that the flavour of fat is agreeable, and that its physical properties render the mastication and deglutition of bread more easy and agreeable; and, in fact, that fat, being taken with bread or flesh, becomes associated with substances which tend to call it into action. In reference to the action of fat when rubbed into the skin, and which has been often shown to be beneficial, I venture to suggest that the probable mode of action is chiefly by modifying the heat-dispersing process by that organ. Inunction of oil has ever been a luxury in hot climates, and particularly after the prolonged use of the hot bath—that is to say, in conditions in which the exhalation of vapour from the skin is exceedingly rapid—also where the direct rays of the sun have induced irritation in the skin. There are also many conditions of system in our own climate in which the skin is too active in relation to the amount of chemical change proceeding within; and hence, with less generation of heat, there is increased waste of it by this great refrigerating organ of the body; and, as a consequence, there is a continually increasing tendency to enervation. If in such cases we cannot increase the appetite, or by any other means increase the vital actions,

by lessening the waste of heat, and thereby the necessity for heat, we effect a positive, although not an equivalent good.

That a layer of oil suffices to close the pores of the skin for a time, and thereby lessens the transpiration of vapour, may be inferred from the action of it when laid upon the spiracles of an insect, or even upon the skin infested with parasites, such as the pedicularis pubis, when it arrests respiration, and the creature dies. Moreover in man, if the skin be well coated with a thick fat which does not liquefy, the transpiration of vapour, and, *a fortiori*, the absorption of heat which occurs with evaporation, and which cools the body, are prevented. This effect will vary with the viscosity and quantity of the oil, the rapidity with which it is removed from the skin, and the frequency of its application. That some of the oil is absorbed and acts as a nutrient is possible; but when it is remembered with how much difficulty fats are absorbed by animal membranes, and by the capillaries in particular, and that this treatment is of use in certain cases only, it is not possible that this is its chief mode of action. The cases fitted for this treatment are those of debility with lessened appetite and feeble digestion, and with moist skin and relaxed tissues. Such are many cases of phthisis and many others recovering from severe and long-continued disease.

But starch and fat, whatever may be their transformations and modes of action, are, as already stated, almost exclusively restricted to that amount of action which will occur in the absence of food, and which, as has been shown, is insufficient to maintain life. When, however, they are associated with certain other substances, as they usually are in nature, they obtain the power to increase the respiratory action above this basis line. This class of substances is very extensive and important, and I have ventured to call them "respiratory excitants." Without some of them we could not live; and prominent amongst them are the well-known *nitrogenous foods*, which hitherto have been presumed to have no connexion with the respiratory process. The cereals contain three members of this class: two nitrogenous, viz., gluten and albumen; and the other non-nitrogenous, viz., sugar. Milk offers sugar as well as a fourth nitrogenous substance, viz., casein. *Casein* and *gluten*, when taken alone, increase the respiratory process to the extent of nearly one grain of carbonic acid per minute, the increase enduring upwards of one and a half hours. They are well known as powerful ferments. Gluten is at the present time a subject of dispute in reference to the value of flours, it being understood that "strong" flour, as it is termed, contains a larger

quantity of gluten, and that the wheat is, *ceteris paribus*, valuable for mixing in proportion to the yield of gluten. This is an important corroboration of the truthfulness of my inquiry into the effects of this substance, and shows that the excito-respiratory elements of wheat are essential to the due action of the starch. In my experiments, however, there was a maximum result obtainable, whatever, within limits, was the amount of gluten taken; and hence it appeared that gluten being present, the quantity of it received within a limited period is not very material. This fact seems to regard gluten as a ferment.

Casein, well washed from skimmed milk, takes the place in milk that gluten occupies in bread, and is an important member of the excito-respiratory class. This substance cannot be properly represented by cheese, since cheese contains much fat, and undergoes secondary changes which render it less easy of assimilation. But it is doubtless to the casein in cheese that must be ascribed the digestive quality, and for this purpose it is known that, whilst a small quantity may be beneficial, a large quantity is a cause of disturbance to the functions of digestion—a fact analogous to that just mentioned in reference to gluten.

Sugar, however, is the most powerful respiratory agent found in milk and cereals, and, of the different kinds, cane-sugar is the most powerful. The effect of one ounce of white sugar dissolved in water is to increase the respiration nearly one grain of carbonic acid per minute in less than eight minutes, and to produce a maximum increase of from one and a half to two and a half grains of carbonic acid per minute in twenty-five to forty minutes, after which period the effect rapidly subsides. The amount of influence is, however, probably in some degree dependent upon the state of the blood, and the rapidity of its absorption into the blood; for in some conditions the addition of an acid increased and shortened its action, whilst an alkali had the contrary effect. The importance, therefore, of sugar with our food is very great, and is in accordance with the appetites of persons of all nations and of all ages. It is probable that certain ill effects have been unduly exaggerated. The great desire for sugar and water on the continent is well explained by the gratifying coolness of the fresh-made beverage, its agreeable flavour and innocuousness, and also by the great freedom and ease of respiration which attends its immediate action. In many of these respects its action is very different from that of alcohol, so much used in this country. The effect upon the respiration is very marked; and, although the quantity of air inspired is sometimes increased so much as one

hundred cubic inches per minute, the great freedom of inspiration seems to indicate a still greater increase. The pulsation was commonly increased, and the pulse became fuller. There was a sense of satisfaction after it had been taken, but this was only for a short time; and after about an hour and a half there was craving for food. Hence it has been with some propriety called by the Germans a "Genuss mittel" and not a "Nahrungs mittel." It does not, in fact, supply the place of food. The component parts of flesh, as albumen, fibrine, and gelatine, are recommended with a view to increase the plastic material and tissues of the body; but whilst they undoubtedly have this power, they also possess an excito-respiratory action, and that in a degree but little inferior to casein and gluten.

Fibrine, as excellent lean beef-steak, has, however, less respiratory action than any of the others. The extreme increase in carbonic acid, after having taken albumen in the form of two eggs, was 1.12 grains per minute; while a maximum increase of between three-quarters and one grain per minute will represent the ordinary influence of gluten, casein, albumen, and gelatine.

Hence we arrive at the important fact that all the nitrogenous foods have, in addition to their power of forming protein compounds, or of otherwise sustaining the changes in the tissues, a most important action over the respiratory changes; and it is now proved that it is one thing to supply respiratory food, and another to call, or aid in calling, that food into action. In illustration of the importance of this class of foods, the following statement is very interesting. In 1853, the prisoners at the Wakefield Gaol lost weight so much that 22.35 per cent. were continually on extra diet. The surgeon, Mr. Milner, advised an addition of half-a-pint of skimmed milk to the general dietary for breakfast, after which the extra diet was reduced to fifteen per cent. in the following nine months, and to fourteen per cent. in 1856. This could not have been due to the amount of nutriment in the milk, but to the nitrogenous compounds acting indirectly. The importance, therefore, of nitrogenous food is thus rendered greater than has been hitherto regarded, and the indivisibility of the two classes of food, viz., respiratory and plastic, is rendered more evident than chemistry has of late years sought to prove. Physiology has ere this shown that, with the body at rest, the evolution of carbon by the respiration is attended with that of nitrogen in the excretions, and that increase of respiration was accompanied by a proportionate increase in the excretion of both carbon and nitrogen, and in such a manner that there was a close correspondence in

the increase of each. Both of these circumstances seem, therefore, to prove not only the indissolubility of the two processes, but that both occur at the same time and also in the same place, viz., in the tissues.

Tea is a substance which has hitherto been regarded as a nutrient^a, because it contains a little nitrogen in its active principle, and has a proportion of gluten in the leaf. Nothing can be clearer from my experiments than that it promotes chemico-vital action, and causes the evolution of more carbon than it supplies; and Lehmann has ere this proved that it increases the elimination of nitrogen. As this is a subject of great interest, I have investigated it in every direction; and, under all circumstances, in every proportion, and in every experiment, it has proved itself to be a powerful respiratory excitant. It is equally efficacious when taken cold, and after it has been prepared two days, as when hot and recently made. Green tea is somewhat more powerful than black; but both kinds, when strong, caused a temporary nausea, or, sometimes, narcotism. The addition of an acid, as is practised by the poorer inhabitants of China and by the Russians of all classes, renders it more stimulating, whilst the addition of an alkali makes it more soothing or narcotic. Both acids and alkalies rather lessen its power, and a fixed alkali totally destroys its influence. Acids, moreover, usually shorten the duration of its action, whilst an alkali prolongs it; but this varies, as the action of acids and alkalies taken alone varies with the existing state of the blood. The maximum increase in the carbonic acid was from one and a half to three grains per minute, and was obtained in twenty-six to fifty minutes; but an increase of a half to one grain per minute was found in ten minutes. The total duration of its influence is usually about two hours. The repetition of small doses, as twenty-five grains every quarter of an hour six times, produced an increase in the evolution of two hundred grains of carbonic acid, a quantity nearly four times that obtained when the whole quantity was taken at once. With this increase of the chemical changes there was an equal increase in the volume of air inspired, and a great increase in the depth of inspiration, accompanied by a sensation of lightness and clearness of the mind, and great ease and completeness in the respiratory effects—results which correspond with popular observation.

As the action of tea has not been understood, it has not

^a See Johnson's *Chemistry of Common Life*.

obtained that place in medicine to which it is certainly entitled; and hence I am desirous to place its action prominently before the profession. A remedy which speedily and most powerfully increases the respiratory function, which has a rapid accumulative action, which can be kept for some days without injury, and taken either in a dilute or concentrated form, must be a good remedy in many diseases. Liebig has with great sagacity pointed out the correspondence between this substance and the active principle of the bile; and there can be no doubt that, with deficient action of the liver, with or without deficient action of the respiration, in relation to the nutritive material and effête matters remaining in the system, tea is a most suitable remedy. In cases of general debility and in phthisis, in both of which we have deficient respiratory action, it seems at first sight to be contra-indicated, because there is already in such cases deficient supply; but even then, when it is conjoined with nutriment, I believe it to be one of the most efficient agents which we possess. The same reasoning, viz., the balancing of waste and supply, will point out the cases in which this agent is not free from harm, so that it is fortunate, perhaps, that the poor woman, with her morsel of bread and her half-a-dozen cups of tea, is obliged to be content with a weak infusion, and a tea not very pure. A very striking illustration may be derived from an experiment made at the Wakefield Gaol, in which Mr. Milner gave one pint of tea for supper instead of one pint of gruel, containing two ounces of oatmeal, and he immediately found the prisoners to lose weight. He then added the tea to the gruel, and found that they still lost weight in a greater degree than with gruel alone. Hence, tea without excess of food may do positive injury. The powerful excito-respiratory action of tea would also probably contra-indicate its action in cases of inflammation of the respiratory organs. There are two other circumstances under which I venture strongly to recommend its use, viz., to soldiers on march in hot climates, and in cases of suspended animation. It has been abundantly proved that the use of spirituous liquors increases the evil effects of exposure to the sun, and that a principal source of danger arises from deficient action of the lungs, as is well pointed out by Mr. Ranald Martin, F.R.S., in his papers recently published in the *Lancet*, and particularly in a very valuable report just published by Mr. Longmore. Moreover, I have proved that with increase of temperature there is diminished respiration and increased pulsation. Tea appears to be very peculiarly fitted to avert the dangers if properly administered, since it not only excites the respiration,

but increases muscular energy, determines to the skin, and thereby cools the body, and that without increasing the pulsation. The proper mode of administration would be for the soldier to carry cold infusion with him, and to drink a due portion (say twenty-five grains) every half hour or hour during exposure.

The same objection to spirituous liquors, and the same advantage from tea, may be applied to cases of restoration from drowning; as an adjunct to other efforts, and the more so that we have no better remedy, it is highly desirable, although its action is not so instantaneous as could be wished. In all such cases the prime object is to restore the suspended respiration, since by it chiefly can the action of the heart be excited and maintained, and the chemical changes renewed.

Coffee has a similar but not quite so powerful an influence over the respiration as tea. It differs, however, from tea in commonly lessening the action of the skin, as shown by the dryness, heat, and pulsation, and increasing the action of the bowels, as proved by the tendency to diarrhoea which occurs from a large dose. Hence, in cases of debility where there is excessive action of the skin—a perspiring and soft skin—with the excessive loss of animal heat which accompanies it, coffee is clearly preferable to tea.

Cocoa and chicory are both respiratory excitants, but in a less degree than coffee; and hence, chicory can only in a modified sense be regarded as an adulteration of coffee.

Coffee-leaves have an action opposed to that of the fruit. They are extensively employed by the poor in the island of Sumatra, and from their cheapness efforts are being made to introduce them into use in Europe. Their action is, however, mildly narcotic, so that they lessen instead of increase the respiratory changes. When taken in doses of half an ounce, the maximum decrease in the carbonic acid was so much as 0.89 grains per minute in myself, and 1.42 grains per minute in another. The quantity of air inspired, and the rate of both respiration and pulsation, all fell. Hence it has the qualities of a valuable febrifuge medicine, and is applicable also to many cases of nervous irritability.

The subject of the action of *alcohols* is one of the greatest interest to the physician, and one which the present state of science has left in a very unsatisfactory state. The term has been made to include every article of food which contains alcohol, viz., all kinds of spirits, wines, and beers; and it is assumed that these various substances have a similar mode of action. Hence, Vierordt drank half a bottle of white wine

and placed the results to the credit of alcohol. Common experience is on this subject far in advance of science; for it is well known that not only has each of the classes just mentioned different effects, but that each member of each class has a special mode and degree of action. Further, various qualities of each of these substances are well recognised, so that our northern friends know well the difference between what is called good and bad whiskey, although each shall be equally strong, or, as is very common, the worst shall be the strongest. The gin-drinker and the rum-drinker are very different men, as are also the gin-drinker and the beer-drinker^a. Moreover, in practice we do not prescribe each of these substances indiscriminately, much less do we ever think of administering seventeen per cent. of alcohol with water instead of giving wine, or six to ten per cent. of alcohol with water instead of beer. Experience has shown that the effect of these articles is not in proportion to the alcohol which they contain, although we have been, with regard to wines and spirits, too much inclined to refer the effect to the alcohol.

It is quite clear that the presence of alcohol in varying quantities is quite insufficient to give a common action to these substances, and hence it would be quite consonant with reason if it were ascertained that their influence over the vital changes of the system varied according to the one selected. Chemical analysis has not done much to elucidate this subject; but we know that wines and spirits contain soluble ethers, and that a good wine is known as much by its aroma or volatile constituents in quantity and quality as by its flavour. Wines also contain sugar, vegetable acids, and salts. Inferior spirits, as raw whiskey, for example, also contain fusel oil. Beers are known to contain sugar and gluten amongst other things, besides alcohol.

I have made these trite remarks because I have found that each member of these classes has a distinct action, and that each one must be studied alone. *Alcohol* does not lessen the respiratory changes, but, on the contrary, rather increases them; and when the quantity is sufficient to act upon the sensorium, the influence is chiefly a disturbing one. Notwithstanding that this result is not in accordance with received opinions, I have not

^a I am informed that in the rum-producing country, Jamaica, it is the habit to drink old rum with water, as an ordinary and oft-repeated beverage, and that it is done with impunity; but, when brandy is substituted for rum, the effect is so different, and so much more injurious, that the change of habit is at once recognised by the acquaintances of the victim.

the least doubt of its truthfulness, for the experiments have invariably given the same results. The maximum increase varied from a half to one and a half grains of carbonic acid per minute, with a corresponding increase in the quantities of air inspired; but, before the experiment terminated, the whole increase was often lost. When a smaller quantity was taken, every fifteen minutes, the effect became ultimately greater, more uniform, and enduring. Böcker remarks that it lessened the appetite; and, consequently, there would be an indirect and secondary diminution in the vital processes. My experiments do not show how alcohol acts; but, from the rapidity of its action (often within five minutes) and the unusual variations in the returns from succeeding experiments, due evidently to a disturbing cause, it is highly probable that it acts, at least in part, through the nervous system, and hence may excite the respiratory function in an indirect manner. It was also proved in our experiments that it lessened the action of the muscles subject to volition, but increased in a certain degree those acting more or less independently of volition; as, for example, those of the heart (the most important effect, I think, of the action of alcohols), and the respiration—a difference not in relation to the structure of voluntary and involuntary muscular fibre, but to a partial suspension of the act of volition, and to contact of the alcohol with the walls of the heart. It is known that sexual intercourse is rendered less possible after having taken alcohol, even in small quantities; and the explanation is probably found in the foregoing paragraph. We also noticed two stages in the effect of all spirits when taken in quantity to affect the sensorium. In the first, there was heat with determination of blood to the skin, lessened volition, and perception of light, sound, and sensation, increased pulsation, jumping inspiration, and merriness of spirits. In the second, sudden sensation of cold, yawning or sighing, feeble respiration, returning consciousness, and taciturnity. There was lessened action of the skin and mucous membranes, and increased action of the kidneys; the former appearing chiefly in the first; the latter, in the second stage. The increase in the respiratory changes was chiefly in the first stage. The sudden sensation of cold; the returning consciousness, and the desire to urinate, occurred nearly simultaneously.

Brandy and *gin*, and particularly the latter, always lessened the respiratory changes. *Whiskey* commonly lessened them, but sometimes it increased them. *Rum* increased them almost always, and to a greater extent than alcohol alone. The nu-

merous experiments which I have made during the last two years, both on myself and others, establish this fact beyond any reasonable doubt.

The vapour of all spirits, when inhaled, decreases the quantity of carbonic acid, but increases the amount of water exhaled from the lungs. The vapour consists of alcohol and the volatile ethers. The vapour of fine old port-wine had the same influence, but in a greater degree. Sherry-wine, when drank in doses of three ounces, had no very marked influence, the effect being sometimes slightly increased, and at others decreased.

Ale and *stout* uniformly and invariably increased the respiratory changes, and maintained the increase for a lengthened period. Rum and milk had a very powerful and enduring influence in increasing the respiratory phenomena, and proved that their influence, as a restorative, is extremely great. The combination, moreover, prevented any effect upon the sensorium.

Hence I draw the following deductions:—

1st. Alcohol does not act principally upon the respiratory function; and when it lessens the vital changes, it does so, not by retarding waste, but by lessening supply. It is a disturber of the system, and cannot be regarded as a food.

2nd. Beers act upon the respiratory function probably by the saccharine and nitrogenous elements, and hence act after the manner of ferments.

3rd. Wine acts upon the respiration probably by its saccharine and acid elements, and increases the respiration in proportion to their quantity, whilst it decreases it in proportion to the excellence and quantity of their volatile elements. Fine old wine lessens the respiration more than a newer and inferior wine.

4th. Rum and ale are true restoratives; that is, they sustain and increase the vital powers; whilst brandy and gin act in a negative manner by lessening action. The old combination of rum and milk is the most powerful restorative with which I am acquainted, but it is less conservative than brandy.

5th. It is probable that the common action of all the spirits in diminishing the action of the skin, and thus lessening the waste of animal heat, has a conservative tendency; whilst their power in increasing the action of the heart is a chief cause of the temporary benefit obtained from them.

The very different action of tea, and such spirits as brandy and gin, is very striking, as the following abstract will show:—

CERTAIN ALCOHOLS.	TEA.
Lessen respiratory action.	Largely increases respiratory action.
Lessen action of skin and mucous membranes.	Increases action of skin.
Increase action of kidneys.	
Increase pulsation.	Rather lessens pulsation.
Decrease consciousness and sensibility.	Increases consciousness, sensibility, and mental perception.
Decrease voluntary muscular action.	Increases all muscular action.
Are followed by reaction and a miserable feeling.	There is no reaction, and the lightness and cheerfulness continue.
Lessen the desire for the supply of food.	Does not lessen supply, but increases waste.

Having thus described the influence of the most important articles of food, I shall conclude this communication with two or three general remarks and a short *resumé* of the principal points which have been indicated:—

1st. It is known that whilst there is a general correspondence amongst men in the food which they desire, there are many exceptions, both in the healthy and diseased system. In my inquiries I found that with a disrelish for an article of food there was less influence from it than under ordinary circumstances, so that, in reference to milk, the effect of every element was less in Mr. Moul (one of the subjects of experiment) than in myself, and neither he nor any member of his family can take milk or cheese. Hence, appetite for food is the expression, not only of desire, but of fitness. Moreover, it was found that in the same person the various substances which were disliked had a common mode of action; also, that with this disrelish there was an unusual enjoyment of some other article having a similar mode of action. Thus, one disliking milk and sugar was very fond of tea. It is, therefore, very questionable how far it is proper to induce a person to take that which he disrelishes (assuming that it is not mere wilfulness), and whether it is not better to seek out and remove the state of system causing the disrelish, and to administer another article of food of an analogous action. Thus, an important meaning is given to that which is commonly regarded as irrational or capricious.

2nd. The effect of small quantities of a substance often repeated is much greater than when the whole is given at once. This was found in both tea and alcohols. Twenty-five grains

of tea, given every quarter of an hour, produced more than three times the effect of one hundred and fifty grains taken at once; and half an ounce of rum, or alcohol, taken every half hour, produced a later but a much more lasting influence. The value of small doses of medicine has been appreciated of late years, but the frequent repetition of them is not sufficiently understood. Hence, one ounce or two ounces of wine are given in an important case at intervals of several, and sometimes of many hours, whereas the influence of the wine begins in a few minutes, obtains its maximum in less than one hour, and soon afterwards disappears or manifests its secondary influence. If a small quantity were given every quarter or half-hour, the stimulating effects would be greater ultimately, and it would be longer sustained. In a case of imminent peril from exhaustion with fever, but with the skin soft, I gave, to a female patient, one wine-glass of port-wine so frequently that six bottles were taken in forty-eight hours, bringing the pulse down progressively from one hundred and fifty to ninety per minute. In such cases the interval should not be greater than half-an-hour.

The importance of the class of "respiratory excitants" having been pointed out, and, in a paper published in the *Medico-Chirurgical Transactions* of 1859, the cyclical variations of the respiratory phenomena having been demonstrated, it is of importance to determine what relation exists between them, viz., whether "respiratory excitants" are more demanded at the season when the respiratory phenomena are the least active. This also applies to climate, and is essentially connected with the influence of the two most powerful members of the class, viz., exertion and cold. It is clear that, in proportion to the amount of starch or other material to be transformed, so must be the necessity for the action of some of the respiratory excitants; and also that in hot seasons the influence of the two most powerful, viz., cold and exertion, is lessened whilst there is a diminution of the respiratory changes. Hence it is highly probable that in the hot season the free administration of certain of the azotized excitants is more necessary than is believed when the amount of carbonaceous food is not materially lessened. The free use of tea and coffee in hot climates is connected with the same requirement; and the necessity for animal food, which is said to occur in prisons during a long imprisonment, is explained by the necessity for respiratory excitants, and not for the plastic action of the nitrogenous food—there being an unusual absence of exertion, and therefore of waste. The diseases of the hot season are those indicating

lessened chemical change, whilst those of cold seasons are such as are commonly associated with highly nitrogenized food and hyperoxygenation*.

The following are some of the principal points to which I wish to draw attention:—

The impropriety of administering arrow-root, or any form of pure starch alone from its deficiency in excito-respiratory material.

The great advantage of supplying oil as it is combined in milk, cream, and flesh.

The imperative necessity for the use of the cereals or milk when we wish to *sustain and increase* the vital powers. The *conservative* action, or *tendency to lessen waste*, of beef-tea and brandy.

The very diverse modes of action, in these respects, of rum and milk on the one hand, and brandy and beef-tea on the other, and the necessity for discrimination as to the action which we desire.

The respiratory as well as plastic action of all animal and nitrogenous substances.

The powerfully stimulating action of tea, both for good and for evil, as the case may be, over all the vital processes of the system, and particularly over those of the skin and lungs. The distinction between tea and coffee in their action upon the skin, and therefore upon the heat-dispersing process.

The very diverse action of brandy and gin from tea, but the nearer approach to similarity with coffee in consequence of their action upon the skin.

The very marked advantage of small and often repeated doses of substances which control nutrition but do not supply nutriment, as tea and alcohol, over large and isolated doses.

The indications of dislikes of foods.

* See a paper "On some of the Cyclical Changes connected with Season," in the Medico-Chirurgical Transactions for 1859.