THE CHEMISTRY OF FOODS AND NUTRITION. I.*

THE COMPOSITION OF OUR BODIES AND OUR FOOD.

"Half the struggle of life is a struggle for food."— EDWARD ATKINSON.

"I have come to the conclusion that more than half the disease which embitters the middle and latter part of life is due to avoidable errors in diet . . . and that more mischief in the form of actual disease, of impaired vigor, and of shortened life, accrues to civilized man . . . in England and throughout central Europe from erroneous habits of eating than from the habitual use of alcoholic drink, considerable as I know that evil to be."— SIR HENRY THOMPSON.

"If we will care for men's souls most effectively, we must care for their bodies also."— BISHOP R. S. FOSTER.

WHAT proportion of the cost of living might be saved by better economy of food; how dietary errors compare in harmfulness with the use of alcohol; whether, as some urge, our next great reform is to be in our dietetics; and to what extent the spread of the gospel and the perfection of its fruit are dependent upon the food-supply, are questions which it is not my present purpose to discuss. I have quoted the foregoing statements, however, because they come with authority, and because, starting from the widely different standpoints of the economist, the physician, and the divine, the conclusions tally perfectly with those of some studies of my own.

Mr. Atkinson cites statistics to show that all but the very few who are especially well-to-do, in this country as in Europe, must expend half or more than half of their earnings for their food; calls attention to our wastefulness, and urges the need of better economy in the purchase and use of food-materials. The error which Sir Henry Thompson most seriously deplores is over-eating. "It is a failure to understand, first, the importance of preserving a near equality between the supply of nutriment to the body and the expenditure produced by the activity of the latter; and, secondly, ignorance of the method of attaining this object in practice, which gives rise to the various forms of disease calculated to embitter and shorten life." Bishop Foster, considering, on the one hand, the destitution that prevails, both at home, and especially in some of the countries where missionary effort is put forth so vigorously, and, on the other, the intimate dependence of man's intellectual and spiritual development upon his physical condition, urges that we may hope for the best culture of the Christian graces in the hearts of men only in proportion as adequate nourishment of their bodies is provided for.

I have been led to the conclusions that, in this country, many people, not only the well-to-do, but those in moderate circumstances also, use a needless quantity of food; that part of this excess, however, is simply thrown away, so that the injury to health, great as it may be, is doubtless much less than if all were eaten; that one great fault with our dietaries is an excess of meats and of sweetmeats; that even among those who desire to economize there is great pecuniary loss from the selection of materials in which the actual nutrients are really, though not apparently, dearer than need be; that many whose means are limited make still more serious mistakes in their choice of food, so that they are often inadequately nourished when they might be well fed at less cost; and, what seems the most painful thing of all, that it is generally the very poor who practice the worst economy in the purchase as well as in the use of their food.

The subject concerns the laboring classes in still other ways. Statistics as well as common observation bear emphatic testimony to the better condition of the American as compared with the European workingman in respect to his supply of the necessaries and comforts of life. Nowhere is this superiority more striking than in the quality and quantity of his food. And the difference in the dietaries of the two is especially marked in the larger amount of potential energy, of capability to yield muscular strength for work and to fulfill other uses in nutrition, which characterizes the food of the American. That the American workman, in many cases at least, turns out more work per day or per year than his European competitor is a familiar fact. That this superiority is due to more nutritious food as well as to greater intelligence is hardly to be questioned. But the better nourishment of the American wage-worker, as we shall see,

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* See "The Food Question in America and Europe" by Edward Atkinson in this magazine for December, 1886.

is largely due to our virgin soil. With the growth of population and the increasing closeness of home and international competition, his own diet cannot be kept up to its present nutritive standard, nor can that of his poorer neighbor and his foreign brother be brought up nearer to that standard, without better knowledge and application of the laws of food-economy.

Some time since, at the instance of the United States National Museum, and in behalf of its food collection, I was led to undertake a study of the chemistry of foods. This has included with other matter a series of analyses of some of our common food-materials. To give some of the more practical results of this work, especially as viewed in the light of late research upon the more general subject of nutrition, is the purpose of the present articles.*

A POUND of very lean beef and a quart of milk both contain about the same quantity of actually nutritious materials. But the pound of beef costs more than the quart of milk, and its nutrients are not only different in number and kind, but are, for ordinary use, more valuable than those of the milk. We have here an illustration of a principle, or rather of two principles, of fundamental importance in the economy of nutrition: our food-materials contain nutrients of different kinds and in different proportions, and the nutrients have different functions, different sorts of work to do in the support of our bodies. Add that it is essential for our health that our food shall supply the nutrients in the kinds and proportions our bodies require, and that it is likewise important for our purses that the nutrients be obtained at the minimum cost, and we have the fundamental tenets of our system of food-economy.

The greater part of our definite knowledge of these matters comes from chemical study of food-materials, and from experiments in which animals are supplied with food of various kinds and the effects noted. In these latter, the food, the *egesta*, solid and liquid, and, in many cases, the inhaled and exhaled air are measured, weighed, and analyzed. Hundreds, indeed thousands, of trials have been made with animals of many kinds, and a great number with human beings of both sexes and different ages. The best work has been done during the last two decades, nearly all of it in Europe, and the larger share in Germany. It involves the study of the profoundest problems of chemistry, physics, and physiology, the most elaborate apparatus, and the greatest care and patience of the workers. The labor of days and weeks is often required for a single experiment of a series, and the result of many series may often be condensed in a very few words. If one seeks famous names in this field he may find them in Liebig, Pettenkofer, and Voit in Germany; Payen and Claude Bernard in France; Moleschott in Italy; and Frankland, Playfair, Lawes, and Gilbert in England, and many others. If he questions the practical value of the results, let him see how they are being applied in the construction of dietaries for the common people in Germany, and what they indicate as to the errors of our food-economy at home. If he would see how results of recent research in one country may be ignored, because unknown, by the writers of a different language in another, let him examine some of our latest magazine articles and text-books, the names of the authors and publishers of which ought to be a guarantee for better things.

What we wish to consider now, however, is not the extent of the science, but some of its more important teachings in their applications to our daily life. Our task is to learn how our food builds up our bodies, repairs their wastes, yields heat and energy, and how we may select and use our food-materials to the best advantage of health and purse.

I begin our study together with a wholesome fear of the editor before my eyes, knowing well that back of the courteous hint to make these articles not too abstrusely scientific there was a repressed warning to avoid the tone and language of the college lecture-room as unsuited to the pages of a magazine. But I must crave a little latitude; the results of scientific research cannot be explained without some tedious technicalities and dry details.

HOW CHEMICAL ANALYSES ARE MADE.

IF I cannot be interesting, I will be orthodox, and go back to the Catechism, whose second question is "Of what are you made?" and the answer, "The dust of the earth." The fact that underlies this answer, namely, the identity of the elements of our bodies with those of the material objects around us, is one of the many which chemistry explains. This fact, embodied in the solemn language of the primeval curse, "for dust thou art, and unto dust shalt thou return," impressed upon us

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* I am indebted to Professor Baird, Secretary of the Smithsonian Institution and Director of the National Museum, for permission to reproduce here several charts prepared to illustrate the food collection; nor can I forbear adding that it was through the generosity of Messrs. Thurber, Whyland and Co., of New York, in defraying a considerable portion of the pecuniary expense of the analyses hereafter referred to that the latter were made possible.

A CORNER IN A CHEMICAL LABORATORY.

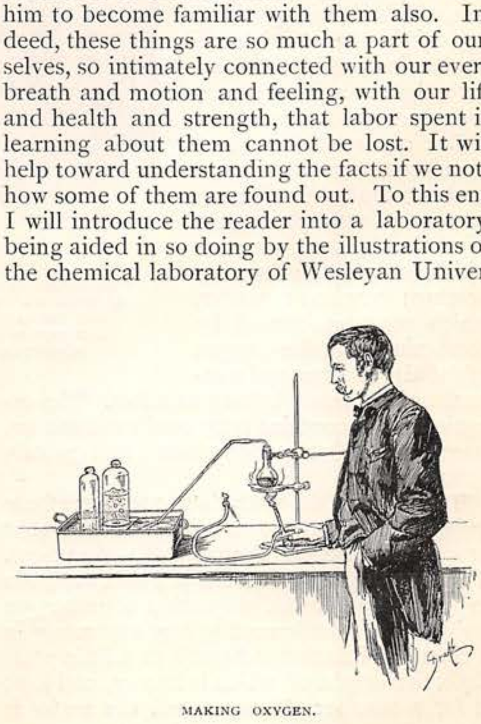
with our earliest religious teachings, clothed in fantastic imagery by poets, and understood so vaguely in the science, and dwelt upon so mysteriously in the philosophy of the past, is divested of much of its mystery by the matter-of-fact investigation of the present. The chemistry of to-day tells us of what elements and compounds our bodies consist. It gives us at least a glimpse of the ways in which they are framed together by the wonderful processes of life, and how they go through the round of growth and fruition, and are by decay resolved again into the forms from which they came. And the research of the past few years has shown us that even this decay is a vital process carried out by living creatures, whose mission is to take off the effete matter and fit it for use again.

A friend of mine tells of an editor of a prominent journal—and a Boston editor at that—who was much surprised to learn that it is possible to tell by use of the balance, the combustion furnace, the filter, and other appliances of the chemical laboratory, just what elements and compounds and what proportions of each make up the air or a mineral, or how much nitrogen there is in muscle or protein in wheat flour. But to the chemist these are the most commonplace, though not always the simplest, things. Indeed, our everyday handling of food materials often involves processes, though crude ones, of analysis.

We let milk stand; the globules of fat rise in cream, still mingled, however, with water, protein, carbohydrates, and mineral salts. To separate the other ingredients from the fat, the cream is churned. The more perfect this separation, *i. e.*, the more accurate the analysis, the more wholesome will be the butter. Put a little rennet into the skimmed milk, and the casein, called in chemical language an albuminoid or protein compound, will be curdled and may be freed from the bulk of the water, sugar, and other ingredients by the cheese-press. To separate milk-sugar, a carbohydrate, from the whey is a simple matter. One may see it done by Swiss shepherds in their rude Alpine huts. But farmers find it more profitable to put it in the pig-pen, the occupants of which are endowed with the happy faculty of transforming sugar, starch, and other carbohydrates of their food into the fat of pork.

The New England boy who on cold winter mornings goes to the barn to feed the cattle, and solaces himself by taking grain from the wheat bin and chewing it into what he calls "wheat-gum," makes, unknowingly, a rough sort of analysis of the wheat. With the crushing of the grain and the action of saliva in his mouth, the starch, sugar, and other carbohydrates are separated. Some of the fat, *i. e.*, oil, is also removed, and finds its way with the carbohydrates into the stomach. The tenacious gluten, which contains the albuminoids or protein and constitutes what he calls the gum, is left. When, in the natural order of events, the cows are cared for and the gum is swallowed, its albuminoids enter upon a round of transformation in the boy's body, in the course of which they are changed to other forms of protein, such as albumen of blood or myosin of muscle; or are converted into fat, or are consumed with the oil and sugar and starch to yield heat to keep his body warm and give him muscular strength for his work or play.

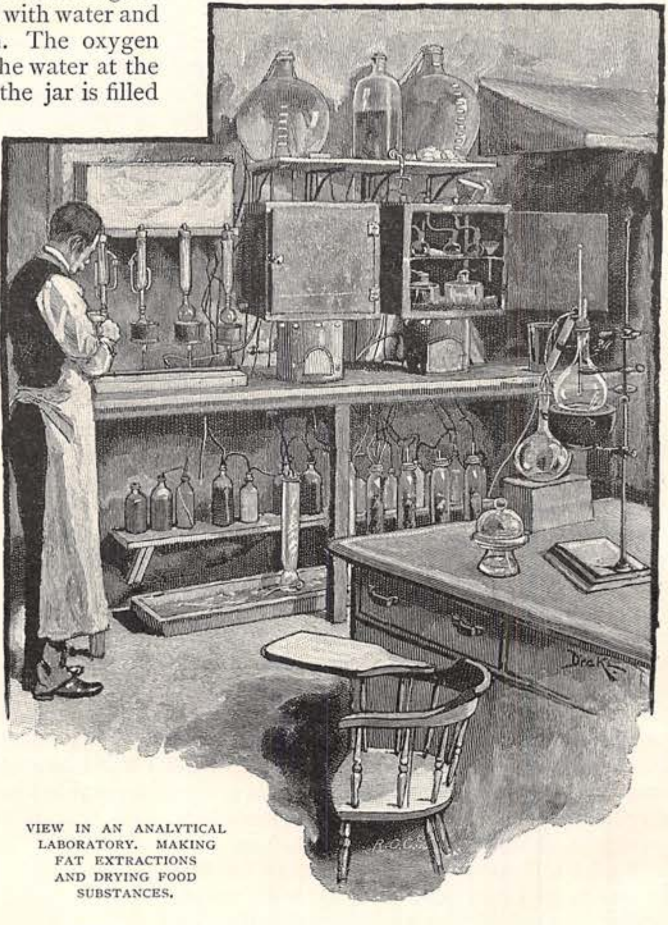
I am using such technical terms as protein and carbohydrates and speaking of chemical processes with which daily usage makes us chemists familiar and which the reader will find referred to so often in these articles that I wish him to become familiar with them also. Indeed, these things are so much a part of ourselves, so intimately connected with our every breath and motion and feeling, with our life and health and strength, that labor spent in learning about them cannot be lost. It will help toward understanding the facts if we note how some of them are found out. To this end I will introduce the reader into a laboratory, being aided in so doing by the illustrations of the chemical laboratory of Wesleyan Univer-



MAKING OXYGEN.

sity. They show the rooms in which some of the studies whose results are to be described beyond were made, and part of the apparatus actually employed.

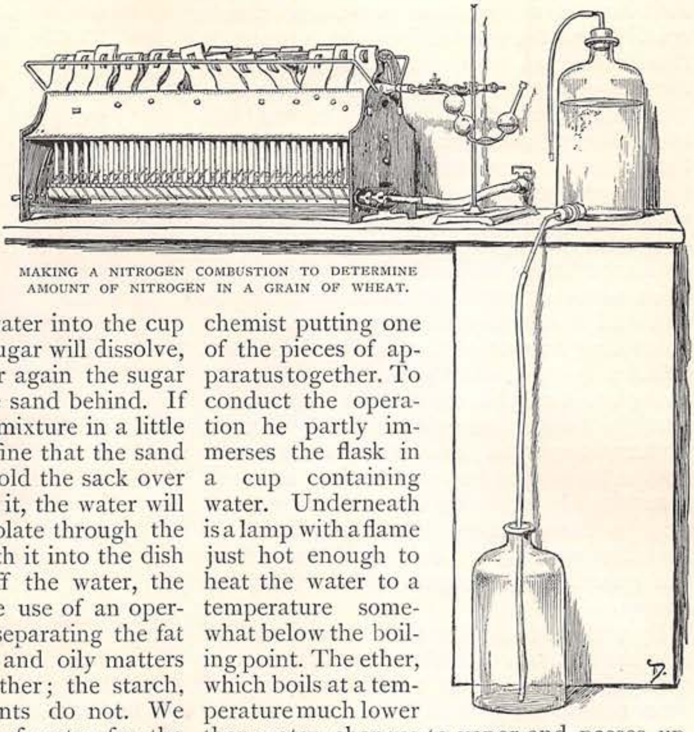
At one of the desks a student may be seen preparing oxygen. In a little flask he places some chlorate of potash—the material which we use as a medicine for sore throat. This he heats by the flame of a peculiar lamp underneath the flask. The oxygen is given off as gas and passes through a glass tube which is bent downward so as to open under the mouth of a glass jar, which latter has been filled with water and inverted over water in a basin. The oxygen bubbles up into the jar, while the water at the same time runs out, and thus the jar is filled with the gas. It looks like ordinary air, but when the experimenter sets fire to a stick of wood, blows out the flame, thrusts the glowing end in the oxygen, it bursts instantly into a brilliant flame. A piece of phosphorus, kindled and placed in the oxygen, burns with a flame of blinding brightness. And a steel wire burns in this gas even more brilliantly than wood burns in ordinary air. Thus the student learns as he could not from text-book or lectures, that oxygen, which makes up nearly two-thirds of the weight of our bodies, and one-fifth of the weight of air, is the great supporter of combustion.



VIEW IN AN ANALYTICAL LABORATORY. MAKING FAT EXTRACTIONS AND DRYING FOOD SUBSTANCES.

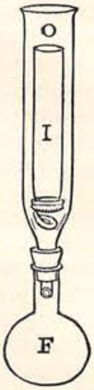
But our special purpose here is to note how chemical analyses are made. Let us take as an example a grain of wheat. It contains water, which we may dry out by heating; organic matter, which may be burned by combining with the oxygen of the air; and mineral matters, which remain behind as ashes. The organic matter contains fatty or oily substances, starch and other carbohydrates, and protein compounds.

The object of the analysis is to separate these ingredients from one another and find what proportion of each is contained in the wheat. To make the analysis, we first grind the grain to flour. To find the proportion of water, we weigh off a small quantity very accurately in a chemical balance and put it in a little glass flask, the weight of which is known, and heat it for a number of hours, until the water is driven out. When it is perfectly dry it is weighed again. The loss in weight represents the quantity of water in the flour. This heating is conducted in a drying oven which is kept hot by a gas flame inside the support on which the oven rests. In order to prevent the action of the oxygen of the air upon the flour while it is being dried, we keep a current of hydrogen gas continually passing through it. The apparatus for generating the hydrogen and forcing it through the flasks is shown in the picture. In the large bottles above is sulphuric acid. This runs down the pipes into the tall narrow glass vessels on the floor. These latter contain zinc. When the acid comes in contact with the zinc, hydrogen gas is developed, and passes up by tubes through the top of the drying oven into the flasks. Such devices as these are necessary if we are to make large numbers of analyses with the greatest accuracy and speed. Like a steam-engine, they seem a little complicated, but the engineer understands his engine, and to the chemist his apparatus seems perfectly simple.



MAKING A NITROGEN COMBUSTION TO DETERMINE AMOUNT OF NITROGEN IN A GRAIN OF WHEAT.

We have next to find out how much oily matter the wheat contains. For this purpose we must have some means of getting the oil out, and weighing it. The operation is by no means a difficult one. Suppose we have a mixture of sugar and sand and wish to find out how much sugar it contains. Sugar dissolves in water, sand does not. If we pour water into the cup containing the mixture, the sugar will dissolve, and if we pour off the water again the sugar will go with it and leave the sand behind. If instead of a cup we put the mixture in a little cloth sack, with meshes so fine that the sand will not pass through, and hold the sack over a dish and pour water into it, the water will dissolve the sugar and percolate through the cloth, carrying the sugar with it into the dish below. If then we boil off the water, the sugar will remain. We make use of an operation analogous to this in separating the fat from our wheat. The fatty and oily matters of the wheat dissolve in ether; the starch, gluten, and other ingredients do not. We therefore use ether in place of water for the solvent. Instead of the bag we place the flour in a little glass cylinder (I) having its lower end covered with filter paper. This small tube is put inside a larger one (O) whose lower end is drawn out into a neck like that of a funnel. This neck is then passed through the stopper of a little flask (F). If now we pour ether into the inner tube, it will dissolve the fat, percolate through the filter paper, and fall into the flask below. By passing successive portions of ether through the flour, we shall, after a time, dissolve out all the fat. But this would require a great deal of time and ether, both of which are expensive. Suppose we had some means by which the ether, after bringing its freight of fat into the flask, could be driven out, leaving the fat behind, caused to return into the inner tube, dissolve another portion of fat and bring it into the flask, and be made to repeat the round again and again. Suppose, furthermore, this operation should be made to go on automatically, and that it could be carried on in several of these pieces of apparatus at once, while the analyst devoted himself to other work. Our analyses would thus be greatly facilitated. Precisely this is done in the apparatus at the left of the drying oven in the large picture, which shows the chemist putting one of the pieces of apparatus together. To conduct the operation he partly immerses the flask in a cup containing water. Underneath is a lamp with a flame just hot enough to heat the water to a temperature somewhat below the boiling point. The ether, which boils at a temperature much lower than water, changes to vapor and passes upward between the inner and outer tubes into a long pipe which winds upward through the tank above like the worm of a still. The tank is kept filled with cold water; the ether vapor is condensed to liquid, falls back upon the flour in the inner tube, dissolves out another portion of fat, carries it into the flask below, and is then once more evaporated, leaving the fat in the flask; and so the same portion of ether keeps on its round, passing up in the form of vapor, coming back as liquid, and bringing fat with it into the flask. When the fat is all extracted the operator takes the apparatus apart, boils off the ether once more, and weighs the flask with the fat. Knowing how much the empty flask weighs, he has simply to subtract its weight from that of the flask with the fat in it; the difference is the weight of the fat.



APPARATUS FOR FAT EXTRACTION.

The ways of finding the amount of nitrogen in food materials are of especial interest to us, because we use the nitrogen as a measure of the amount of protein, the most important of the nutritive ingredients. One of the most common of these ways, the "soda-lime method," as it is called in the laboratory, is illustrated in pictures herewith. The flour is heated with a mixture of soda and lime in a combustion-tube. The small diagram shows the tube ready for the heating or "combustion," as it is termed. Connected with the long combustion-tube which holds the flour and soda-lime is a bulb-tube containing a little acid. When the combustion-tube is heated in the furnace, as shown in the larger picture, the nitrogen of the flour is changed to ammonia, which is caught in the acid in the bulb-tube. When this is done we have only to find the amount of ammonia and calculate from it the amount of nitrogen. The picture of a chemist sitting by the window shows this latter operation. He has poured the contents of the bulb-tube into a dish called a beaker, added a few drops of litmus, which colors the liquid red, and is carefully drawing another liquid containing ammonia from an upright tube, called a burette, into the beaker. When just enough to neutralize the acid has been drawn into the beaker the color suddenly changes from red to purple. The burette is marked so that he knows just how much of the ammonia is required to neutralize the acid not neutralized by the ammonia from the wheat, and thus the quantity of the latter, and with it the quantity of nitrogen in the wheat, are known.

By such operations as these we are enabled to make analyses of different food materials, of the tissues and fluids of the body, and of other substances as well.

THE CHEMICAL ELEMENTS AND COMPOUNDS OF THE BODY.

BEFORE entering upon our study of foods it will be well to consider with some detail the composition of the human body. For a brief statement of the elements nothing can serve us better than the accompanying reproduction of some of the case-labels of the food collection in the United States National Museum at Washington. The figures are as computed by Messrs. E. A. Welch and R. H. Pomeroy, students in this laboratory, who have been at more pains than any one else, so far as I am aware, to use data collated from all available sources. No one has ever made a complete chemical analysis of a human body, but anatomists have made numerous weighings of the different organs, and chemists have analyzed their constituents. From the figures thus obtained it is possible to make an approximate estimate of the composition of the body of an average man, as is here done.

The diagram on the opposite page will help to a clearer idea of the relative proportions of the elements in the body. In the latter the proportions are expressed in percentages, while in the National Museum labels the estimated weights are stated in pounds.

These thirteen elements are combined with one another in the body, forming a great variety of compounds. Chemists have discovered more than a hundred different compounds in the bodies of man and other animals. Instead of attempting to enumerate all of them here, it will be more to our purpose to consider some of the principal ones. In doing so we may take advantage of the fact that the compounds in the body and those in the food are very similar, and discuss them together.

DETERMINING THE AMOUNT OF AMMONIA WHICH CAME FROM THE NITROGEN OF THE WHEAT.

An ox eats grass and meal and transforms the compounds they contain into meat. We eat meat and wheat and change them into the materials of our bodies. Some of the compounds in the food are destroyed, others are only slightly changed in these transformations.

Water, which consists of the two elements hydrogen and oxygen, is a most important constituent of all animal and vegetable tissues. It makes up about seven-eighths of the whole weight of milk and of the flesh of oysters, one-fourth that of potatoes and very lean meat (muscle), one-third of bread, a little over half of well-fattened beef or mutton, and one-eighth of the weight of flour and meal. The body of an average man would, by the above calculation, contain about sixty-one per cent. or three-fifths water.

Of the materials of our bodies and of our foods the larger part is combustible, as was the case with the grain of wheat; that is to say, it will be burned if put in the fire. A small residue will, however, remain as ashes. This incombustible portion includes the so-called mineral matters. These latter consist of the metals potassium, sodium, magnesium, calcium, and iron, combined with other elements, as oxygen,

CHART I.—CHEMICAL COMPOSITION OF THE HUMAN BODY.

ELEMENTS.

The chemical compounds of which our bodies are made up are shown by chemical analysis to consist, mainly, of thirteen elements.

Five of these elements are, when uncombined (*i. e.*, each by itself and not united to any other element), gases. They are named:

1. Oxygen, 2. Hydrogen, 3. Nitrogen, 4. Chlorine, 5. Fluorine.

The other eight are solid substances. Of these, three are non-metals:

6. Carbon, 7. Phosphorus, 8. Sulphur.

The remaining five are metals:

9. Iron, 10. Calcium, 11. Magnesium, 12. Potassium, 13. Sodium.

Besides the above thirteen elements, minute quantities of a few others, as silicon, manganese, and copper, are found in the body.

CARBON—A SOLID.

The body of a man weighing 148 pounds would contain about 31 pounds of carbon.

The diamond is nearly pure carbon. Graphite (the so-called "black lead" of lead-pencils), anthracite coal, coke, lamp-black, and charcoal are impure forms of carbon.

Carbon exists in combination with other elements in the body, of which it makes about one-fifth the whole weight, and in food.

Carbon burns, *i. e.*, combines with oxygen. In this combustion, heat and force are generated and carbonic acid gas formed. The carbon taken into the body in food combines with the oxygen of the inhaled air, yielding heat to keep the body warm and force, muscular strength, for work. The carbonic acid is given out by the lungs and skin. Carbon thus serves as fuel for the body and is the most important fuel element.

PHOSPHORUS—A SOLID.

About 1 pound and 6 ounces of phosphorus would be found in the body of a man weighing 148 pounds.

Phosphorus is a non-metal, light, very inflammable, and so soft that it is easily cut with a knife. Since it burns so readily in air, it is here kept under water.

United with oxygen, phosphorus forms what is known as phosphoric acid. This, with lime, makes phosphate of lime. Most of the phosphorus of the body occurs in this form in the bones and teeth, though it is also found in the flesh and blood, and especially in the brain and nerves.

The composition of the bodies of different persons varies greatly with age, size, fatness, etc. The amounts of the several elements in the body of an average healthy man, five feet eight inches high, weighing 156 pounds with, and 148 pounds without, clothing, may be roughly estimated to be, in pounds and hundredths of a pound, somewhat as follows:

WEIGHTS OF CHEMICAL ELEMENTS IN THE BODY OF A MAN WEIGHING 148 POUNDS.

Oxygen	92.4 pounds
Carbon	31.3 "
Hydrogen	14.6 "
Nitrogen	4.6 "
Calcium	2.8 "
Phosphorus	1.4 "
Potassium	.34 "
Sulphur	.24 "
Chlorine	.12 "
Sodium	.12 "
Magnesium	.04 "
Iron	.02 "
Fluorine	.02 "
Total	148.00 pounds

HYDROGEN—A GAS.

The body of a man weighing 148 pounds is estimated to contain about 14½ pounds of hydrogen, which, if set free, would fill about 2600 cubic feet.

Hydrogen, when uncombined, is a gas. It is the lightest substance known. Combined with oxygen it forms water, of which it constitutes one-ninth of the whole weight. Hydrogen occurs in combination with other elements in the body and in food.

Hydrogen, like carbon, unites with oxygen of the inhaled air in the body, thus serving as fuel. The water produced is given off in the respiration through the lungs, and as perspiration through the skin.

CALCIUM—A METAL.

The body of an average man weighing 148 pounds has been estimated to contain some 3 pounds of calcium.

Calcium is a metal somewhat similar in appearance to magnesium or zinc. It is very difficult to obtain free from other elements. United with oxygen it forms lime. This, with phosphoric acid, makes phosphate of lime, the basis of the bones and teeth, in which nearly all the calcium of the body is found. With carbonic acid, it forms carbonate of lime, the chief ingredient of marble and limestone.

LABELS FROM CASE OF SPECIMENS, ILLUSTRATING COMPOSITION OF HUMAN BODY, IN FOOD COLLECTION OF NATIONAL MUSEUM.

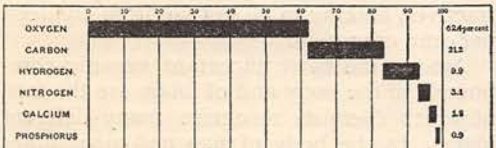


DIAGRAM I.

ESTIMATED PROPORTIONS OF CHEMICAL ELEMENTS.

phosphorus, sulphur, and chlorine. Thus, in bone we have phosphate of lime or calcium phosphate, which consists of calcium, phosphorus, and oxygen; in muscle, potassium phosphate and potassium chloride, the latter a compound of potassium and chlorine, and so on. The mineral matters make about thirty per cent. of the weight of bone, one per cent. of the flesh and blood of animals, and from one-half of one to two per cent. of our ordinary vegetable food materials. The mineral matters constitute about six per cent. of the whole weight of the body of an average man.

The combustible portion of the body and of the food that nourishes it consists of so-called organic compounds. Since these are the most important substances we shall have to do with in our study of foods and nutrition, we ought to have a tolerably clear understanding of the nature of at least the principal ones.

If from a piece of meat we remove the bone, gristle, and fat as completely as practicable, and subject the remaining "lean" (muscle) to chemical analysis, we shall find about one-fourth, or, to speak more accurately, from twenty-two to thirty per cent., of it to consist of organic compounds, the rest being water with a very little mineral matter. Even if all the visible fat is removed, part of this organic matter will consist of fat in microscopic particles. The fatter the animal from which the meat comes, the more of these minute particles of fat and the less water will there be in the muscle, a fact, by the way, which has the most interesting bearing upon the composition of our own bodies, as we shall see later on. If, however, we assume that the fat and the mineral matter are both out of the way, some very remarkable compounds will remain. The bulk will consist of substances very similar to the albumen or "white" of eggs, and hence called albuminoid — albumen-like — compounds. They are sometimes called proteids, but the name albuminoids is perhaps preferable. Albuminoids in different forms make the basis of blood and muscle. Fresh blood contains blood-albumen and other albuminoids; coagulated blood contains fibrine. Muscle contains muscle-albumen, and other albuminoids called syntonin and myosin. The last is the chief constituent, except water, of muscle. Many persons are surprised to learn that myosin, instead of being the tenacious substance of which muscle is commonly supposed to consist, is in living muscle probably liquid or semi-liquid. How the contractile power of the muscle of an athlete can be exerted by liquid or semi-liquid matter is one of the unsolved problems of chemical physiology.

Albuminoids occur in great variety in plants as well as in animals, but they all consist of the four elements carbon, oxygen, hydrogen, and nitrogen, with perhaps a little sulphur or phosphorus.

Along with muscle, the meat contains what we call gristle, the substance that bothers us so much when we try to carve with a dull knife. This name, however, is applied to several substances, as tendon and cartilage, which, with skin and bone, etc., are called connective tissues. These tissues consist mainly of compounds like the collagen of tendon and the ossein of bone. They are very similar to gelatin (glue) and are changed to gelatin on heating with water. They are hence termed gelatinoids. The gelatinoids are thus the principal ingredients of connective tissue, as albuminoids are the principal ingredients of muscle and blood. The gelatinoids consist of the same elements as the albuminoids; these two classes differ from the other organic compounds in that they contain nitrogen, which most of the others do not.

In speaking of the ingredients of foods, it is customary to give to both albuminoids and gelatinoids the generic name of protein. Protein compounds are the most important of all the ingredients of foods.

There is still another class of nitrogenous substances in meat which, though so small in quantity as to be often left out of account, are nevertheless extremely interesting. These are known in the chemical laboratory as creatin, creatinin, carnin, etc., and are designated collectively as "extractives," because they are extracted from flesh by water, as in the case with beef tea and Liebig's Meat Extract.

Chemists find certain analogies between these extractives from flesh and thein and caffein, the active principles of tea and coffee, which they likewise resemble in their stimulating effect. The African traveler Rohlfs tells how invigorating he found a little meat extract spread on a piece of dry bread. The familiar fact that dogs that are quiet and subdued with vegetable food grow fierce on meat is most probably explained as the effect of these same substances. Some people, oftenest those of a fine nervous organization, I presume, find in meat a stimulating effect approaching that of wine. The extractives are similar to alcohol in that they do not form tissue, flesh, or fat. They have, apparently, no effect as fuel. In brief, they are stimulants rather than nutrients.

The extractives give the taste to fresh meat. They impart their savory smell and taste to soups, give roast beef its appetizing odor, and steak its toothsome taste. Our craving for meat is largely due to our fondness for these extractives, as the tastelessness of meat from which they have been removed in making soups bears witness. Indeed, I mistrust that the excessive use of meat, from which the average gourmand — and many of us are veritable gourmands in this respect — suffers so much harm to health, is traceable to the redolence and relish of creatin and other extractives. Though the extractives are different from true protein compounds, they contain nitrogen, and we may follow a common usage and class them as protein.

The body of an average man will contain about eleven per cent. of albuminoids, a little over six of gelatinoids, and about one of extractives, making in all not far from eighteen per cent. of protein.

Among the most important organic compounds of the body and of foods are the fats, of which chemists recognize many different kinds. In the body of man and many other animals, the principal ones are stearin, palmitin, and olein. Stearin, which is obtained in large quantities from beef tallow, is much used for candles, because it does not melt readily. Olein, on the other hand, is an oil at ordinary temperature, and is a chief ingredient of olive oil. A large part of the fat of the human body consists of olein. The fats just named consist of the three elements carbon, oxygen, and hydrogen.

The brain, nerves, and spinal cord contain substances called protagon, lecithin, cerebrin, etc., which, though commonly classed as fats, contain nitrogen and phosphorus, and are therefore known as nitrogenized and phosphorized fats. They have an especial interest because they are believed to be somehow connected with mental activity.

The fats make up about sixteen per cent. of the weight of an average man.

The other compounds in the body are so small in amount that we might pass them by. One class, however, the carbohydrates, demand a moment's notice, because they make up a large part of our food. These include sugar, starch, dextrin, and like substances. The principal ones in the body are glycogen, or liver-sugar, and inosite, or muscle-sugar. They consist of carbon, oxygen, and hydrogen, the same elements as occur in the fats, though not in the same proportions. They constitute only a fraction of one per cent. of the weight of a healthy human body.

To recapitulate, the estimated weights of these compounds in the body of an average man weighing 148 pounds, or, with clothing, 156 pounds, may be stated as in the figures below. The percentage composition is set forth more graphically in Diagram II.

DIAGRAM II.— ESTIMATED PROPORTION OF CHEMICAL COMPOUNDS IN THE HUMAN BODY.

Compounds in the Body of a Man weighing 148 Pounds.

Water	90.0	pounds
Protein	26.6	"
Fats	23.0	"
Carbohydrates	0.1	"
Mineral matters	8.3	"
Total	148.0	pounds.

Of course I do not mean that this is an exact statement of the amounts of the compounds in the body of any given man or of an ideal man. These figures, like those above cited for the elements, are simply an attempt to show in a general way in about what proportions the materials probably occur in the body of an ordinary man of average size and weight. The bodies of different people vary widely in composition. The flesh of lean persons has more water, and that of fat persons more fat, in proportion to the whole weight. A lean man may gain in weight without corresponding gain of muscle or other protein compounds. The store of fat in his body increases. Part of this fat accumulates in adipose tissue next to the skin and in other masses such as we see in meats. Part is disseminated in small particles through the muscles, bones, and other tissues.

In studying the tissues of animals we find a considerable proportion of these particles of fat to be so small as to be visible only by aid of a powerful microscope. A piece of muscle in which no fat can be seen with the naked eye may yield a considerable quantity of fat when treated with ether in the apparatus for fat-extraction. The muscles, bones, and other tissues contain large proportions of water. As the fat accumulates in them, part of the water goes out to make way for it. When, on the other hand, fat is removed from the living tissues, more or less of the water is restored.*

Accordingly a gain of weight of the body may mean a gain, not only of a corresponding weight of fat, but of enough more fat to make up for the water that is lost. To " get stout " is really to grow fat faster than the scales tell us, and to grow lean is to grow watery.

Of course gain of weight of the body may be due to increase of other materials than fat, as in the case of growing animals. So, too, there may be increase of protein with loss of fat, as in the muscle of an athlete when in a course of training.

PROPORTIONS OF NUTRITIVE INGREDIENTS IN FOOD MATERIALS.

HAVING learned what our bodies consist of, we have next to study the composition of the food by which they are nourished. Viewed from the standpoint of their uses in the nutrition of man, our food materials may be regarded as consisting of edible material and refuse, and the edible material as made up of water and nutrients. The accompanying adaptation of charts prepared for the food collection of the National Museum summarize what is most necessary to say here about the constituents of food.

We have next to notice the amounts of these ingredients in different food materials. The details will perhaps be best explained by an example.

CONSTITUENTS OF SPECIMEN OF SIRLOIN OF BEEF.

	In flesh, edible portion.	*In meat as bought, including refuse.*
	Per cent.	*Per cent.*
Refuse, bones, etc.	None.	25
Water	60	45
Protein	20	15
Fat	19	14¼
Mineral matters	1	0¾
Total	100	100

As stated above, some fat sirloin of beef was found to consist of about one-fourth refuse

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* This statement is based not only upon observations recorded in memoirs and text-books of physiological chemistry, but also upon a somewhat extended series made in this laboratory but still awaiting publication. It rests upon the assumption that the changes in composition of the tissues of the human body are similar

CHART II.—INGREDIENTS OF FOOD MATERIALS.

NUTRIENTS AND NON-NUTRIENTS.

Our ordinary food materials, such as meat, fish, eggs, potatoes, and wheat, etc., consist of:

REFUSE—as the bones of meat and fish, shells of eggs, skin of potatoes, and bran of wheat.

EDIBLE PORTION—as the flesh of meat and fish, white and yolk of eggs, wheat flour.

The edible substance consists of:

WATER,
NUTRITIVE INGREDIENTS OR NUTRIENTS.

The principal kinds of nutrients are:

1. PROTEIN,
2. FATS,
3. CARBOHYDRATES,
4. MINERAL MATTERS.

The water, refuse, and salt of salted meat and fish are called non-nutrients, because they have little or no nutritive value. The water contained in foods and beverages has the same composition and properties as other water; it is, of course, indispensable for nourishment, but is not a nutrient in the sense in which it is here used. In comparing the values of different food materials for nourishment, we may leave the refuse and water out of account and consider only the nutrients.

CLASSES OF NUTRIENTS.

The following are familiar examples of compounds of each of the four principal classes of Nutrients:

PROTEIN {
a ALBUMINOIDS: *E. g., Albumen (white) of eggs; casein (curd) of milk; myosin, the basis of muscle (lean meat); gluten of wheat, etc.*
b GELATINOIDS: *E. g., Collagen of tendons; ossein of bones, which yield gelatin or glue.*

Meats and fish contain very small quantities of another class of compounds called "extractives" (the chief ingredients of beef tea and meat extracts), which contain nitrogen, and hence are commonly classed with protein.

FATS { *E. g., Fat of meat; fat (butter) of milk; olive oil; oil of corn, wheat, etc.*

CARBOHYDRATES { *E. g., Sugar, starch, cellulose (woody fiber).*

MINERAL MATTERS { *E. g., Calcium phosphate, or phosphate of lime; sodium chloride (common salt).*

It is to be especially noted that the protein compounds contain nitrogen, while the fats and carbohydrates have none. The average composition of these compounds is about as follows:

	Protein.	*Fats.*	*Carbohydrates.*
Carbon	53 per cent.	76.5 per cent.	44 per cent.
Hydrogen ...	7 "	12.0 "	6 "
Oxygen	24 "	11.5 "	50 "
Nitrogen	16 "	None	None
	100 "	100.0 "	100 "

bone, etc., and three-fourths edible flesh. The edible portion was analyzed and found to contain, approximately, sixty per cent. of water and forty per cent. of nutrients. Of the nutrients the protein constituted, in round numbers, twenty, the fats nineteen, and the mineral matters one per cent.

Such numerical statements, however, are not entirely satisfactory, especially when a number are to be studied at once. Diagram III. (pages 70 and 71), in which the proportions of the ingredients are indicated by shaded bands, will doubtless be more acceptable.

Until within the past dozen years very little attention has been given in this country to the chemistry of animal and vegetable products, and most of the work actually done has had reference to their agricultural values. With the exception of analyses of cereals and dairy products we have very few American studies of materials used as food for man, aside from those referred to above as executed in behalf of the National Museum, and a series of investigations of the chemistry of food-fishes made for the United States Fish Commission. Much more work in this direction, including the more purely scientific study of the constitution of the materials, is, therefore, most pressingly needed. At the same time the analyses at hand, which have been used in compiling the figures of the diagram, will suffice to give a general and, I think, tolerably correct idea of the average composition of the materials. In some cases where American analyses are lacking, particularly of vegetable foods, I have used European analyses, of which a large number are on record.

I ought to say that different specimens of the same kind of food material may vary

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to those found to take place in the bodies of other animals. It is by no means urged that the quantities of water and fat which thus mutually replace each other are exactly the same. A striking illustration of the mutual replacement of water and fat may be seen in the case of the lean and the fat mackerel in Part II. of the double-page diagram of composition of food materials beyond.

widely in composition and that the analyses here given represent averages. Examples of these variations are shown in the cases of oysters and of mackerel in Part II. of the table. In these, however, the differences are unusually wide, although very considerable variations are found in other materials, especially in meats.

The diagram tells its story plainly, and I need now call attention to but few points. It is interesting to note, in Part I., the differences in the amounts of refuse and edible portion in the different kinds of meats, fish, etc., as they are ordinarily found in the markets. Thus in some of the specimens of beef, as the round steak, the bone and other inedible materials amount to only ten per cent. of the whole, whereas in the flounder the refuse amounts to two-thirds, and the edible portion to only one-third, of the whole. The bone, though counted here as refuse, yields, when properly boiled, a considerable quantity of nutritive matter, chiefly in the form of gelatine and fats. Fish, as we buy them in the markets, have on the average a larger proportion of refuse and less edible material than meats. Dairy products and most vegetable foods have very little refuse.

In examining the edible portion of the materials, as shown in Part II., it is interesting to note the wide variations in the proportions of water and of nutritive substances. In general the animal foods contain the most water and the vegetable foods the most nutrients, though potatoes and turnips are exceptions, the former being three-fourths and the latter nine-tenths water. Butter, on the other hand, though one of the animal foods, has on the average about nine per cent. of water. The milk from which it is made is not far from seven-eighths water. As stated above, meats have more water in proportion as they have less fats, and *vice versâ*, the fatter the meat the less amount of water in it. Thus, very lean beef (the muscle of a lean animal from which the fat has been trimmed off) may have seventy-eight per cent. of water and only twenty-two per cent. of nutrients. The rather fat sirloin of the diagram has sixty, and the very fat pork only about ten per cent. of water. The flesh of fish is in general more watery than ordinary meats, that of salmon being five-eighths water; codfish, over four-fifths; and flounder, over six-sevenths. Flour and meal have but little water, and sugar almost none.

In examining the proportions of individual nutrients, protein, fats, and carbohydrates, the most striking fact is the difference between the meats and fish, on the one hand, and the vegetable foods on the other. The vegetable foods are rich in carbohydrates, starch, sugar, etc., while the meats have not enough to be worth mentioning. On the other hand the meats abound in protein and fats, of which the vegetable foods usually have but little. Beans and oatmeal, however, are rich in protein, while fat pork has very little.

The comparative composition of oysters and milk is worth noting. Both contain about the same total amounts of nutrients, but the proportions are quite different, the oysters having the more protein, and the milk the more fat. Roughly speaking, we may say that there is not a very great deal of difference between the nutritive values of a quart of oysters and a quart of milk. Considering the cost, however, the oysters are far the more expensive food.

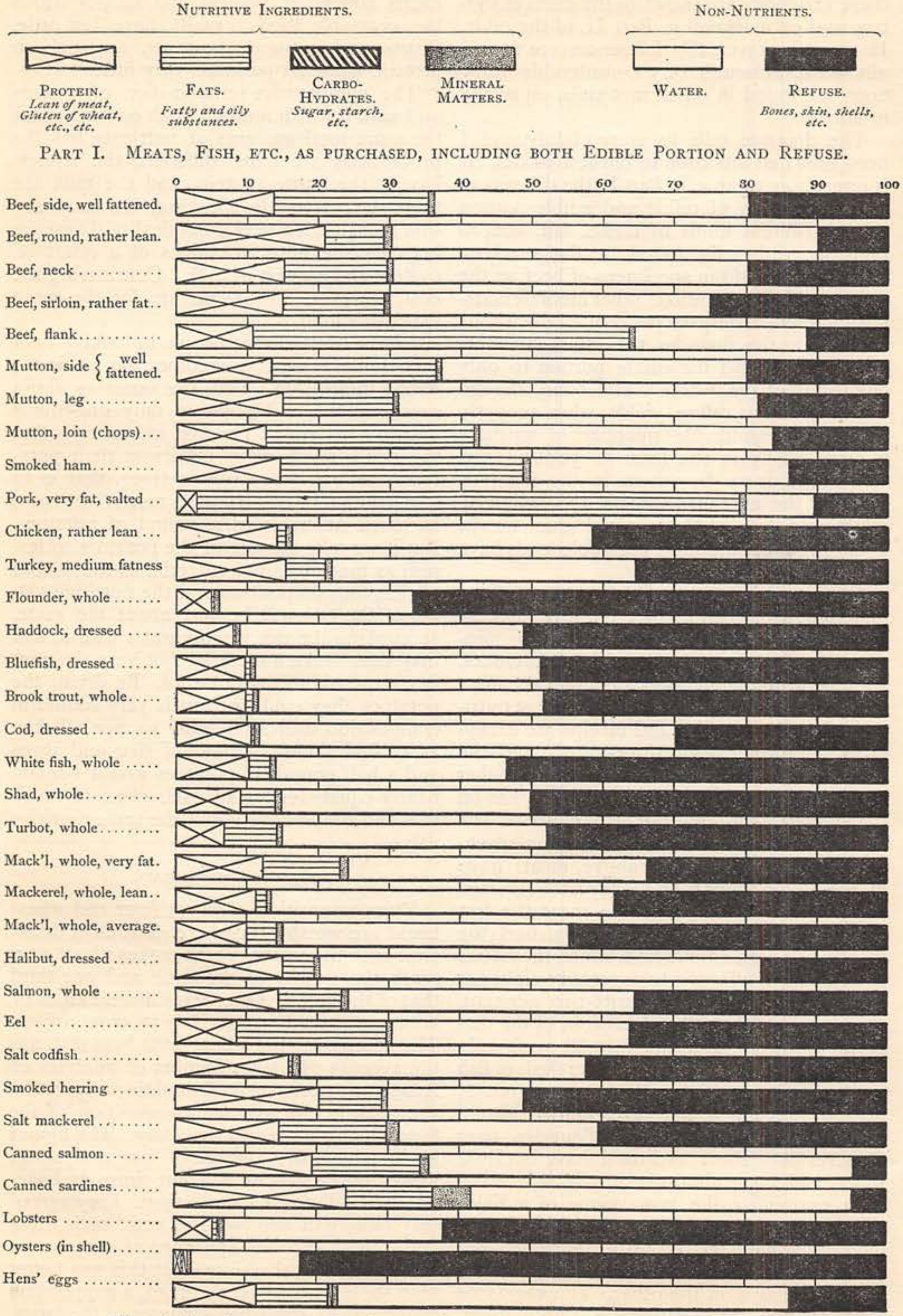
I have noticed that people in looking over such tables as this sometimes get at first a wrong impression. Thus rice contains about seven-eighths, and potatoes only one-fourth nutritive material. The first inference is that the rice is much more nutritious than potatoes. In one sense this is true; that is to say, a pound of rice contains more than twice as much nutrients as a pound of potatoes. But if we take enough of the potatoes to furnish as much nutritive material as the pound of rice, the composition and the nutritive values of the two will be just about the same. In cooking the rice we mix water with it, and may thus make a material not very different in composition from potatoes. By drying the potatoes they could be made very similar in composition and food value to rice. Taken as we find them, a pound of rice and three and a half pounds of potatoes would contain nearly equal weights of each class of nutrients and would have about the same nutritive value.

FLOUR AND BREAD.

THE composition of wheat flour and wheat bread are worth notice here. The chief difference is in the water, which makes about one-ninth the weight of the flour and one-third that of the bread. Of course different kinds of flour and bread vary widely in composition. The composition of wheat flour here stated is the average of a large number of analyses of American specimens, and doubtless represents very closely the average composition of the flour which people ordinarily buy. The figures for bread are the average of four analyses of loaves purchased at different times at bakeries in Middletown, Connecticut. They agreed very closely in composition with each other and with an excellent specimen of home-made bread. I infer, therefore, that this was better than the average baker's bread, a supposition confirmed by published analyses of the latter,

DIAGRAM III. NUTRITIVE INGREDIENTS, WATER, AND

PERCENTAGES OF THE DIFFERENT CONSTITUENTS


PART I. MEATS, FISH, ETC., AS PURCHASED, INCLUDING BOTH EDIBLE PORTION AND REFUSE.

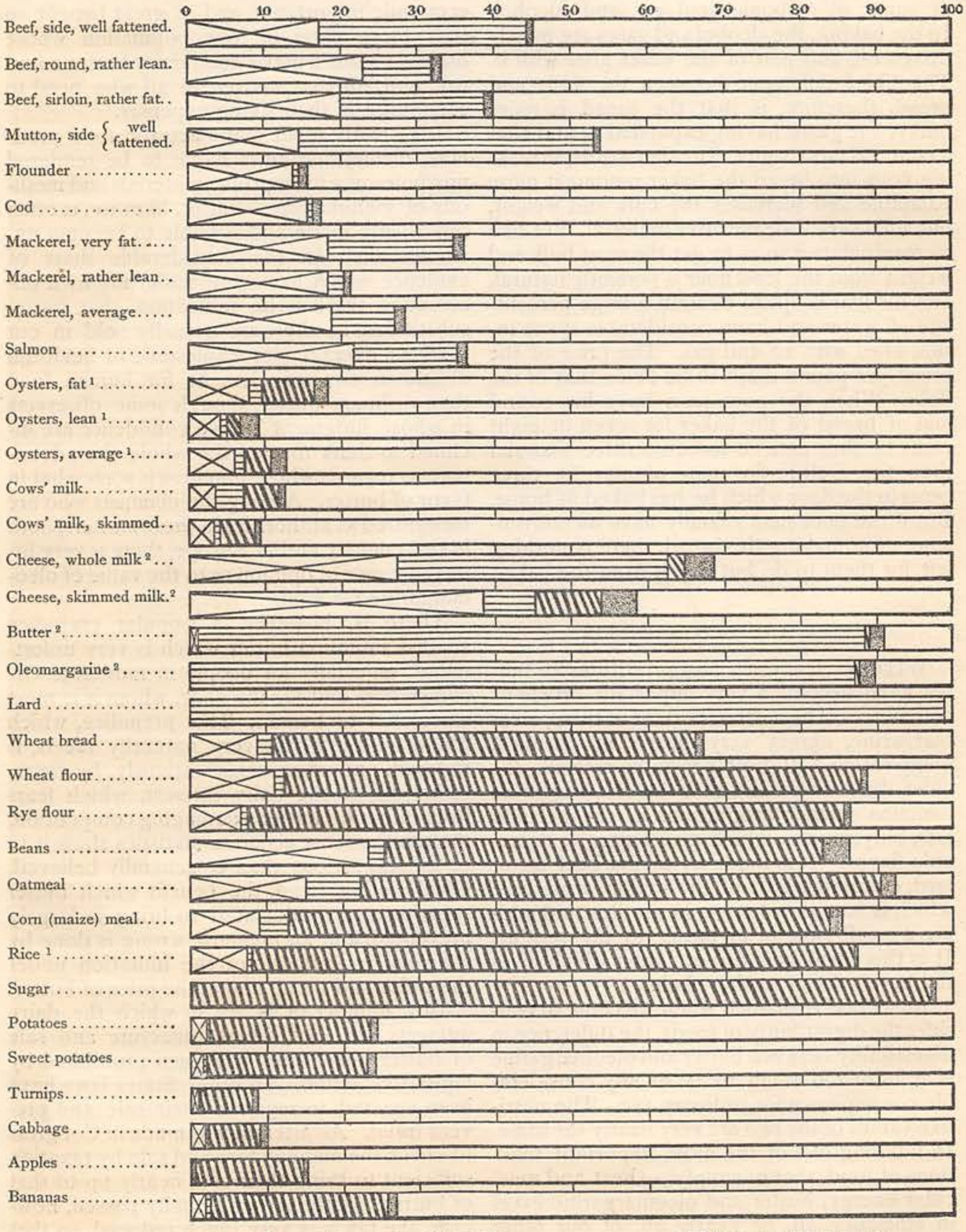
Where the ingredients amount to less than one-half of one per cent. they are omitted from this table.

REFUSE IN SPECIMENS OF FOOD MATERIALS.

INDICATED BY SHADED DEVICES.

EXPLANATIONS.—Of the different classes of nutritive ingredients or nutrients of food the protein compounds ("muscle-formers") are the most important in the sense that they alone form the basis of the blood, muscles, tendons, and other nitrogenous tissues of the body. Protein, fats, and carbohydrates of food are all transformed into the fat of the body and all serve as fuel to yield heat and energy (strength) for muscular work. As fuel, one part by weight of fats is estimated to be equivalent to over two parts of protein or carbohydrates. A proper diet will include all the nutrients in proportions fitted to the needs of the user.

PART II. MEATS, FISH, ETC., EDIBLE PORTION; DAIRY PRODUCTS; VEGETABLE FOODS.



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[1] In respect to quantity of nutrients.

[2] Mineral matters include salt.

which often show a much larger percentage of water, sometimes forty per cent. or more. In using the word "better" I do not refer to flavor, color, or texture, but to the proportion of nutrients and water. In making bread, a very little butter or lard and yeast and a good deal of water, by itself or in milk, are added to the flour. In the fermentation of the dough in rising, minor transformations take place in the carbohydrates, the chief being the change of sugar to carbonic acid gas and alcohol. In the baking, the alcohol and gases are mostly driven off, and part of the water goes with it. The chief difference between the flour and bread, therefore, is that the bread is more bulky, the gases having expanded it, and that it contains more water. In other words, in making flour into bread the baker renders it more palatable and increases the bulk and weight, but adds very little nutritive material. For him to manipulate it so as to get the most bulk and weight from the least flour is perfectly natural, and his loaf is apt to contain a large percentage of water and have considerable space inside filled with air and gas. The price of the bread per pound is apt to be twice that of the flour. When the poor man buys his pound loaf of bread of the baker for seven or eight cents he thus gets no more nutritive material than the well-to-do man obtains for three cents in the flour which he has baked at home. But if the poor man's family have no conveniences for making the bread, there is nothing left for them to do but buy it from the baker.

BUTTER AND OLEOMARGARINE.

WITHIN a few years past substitutes for butter have become a very important article of commerce. The most important of these, oleomargarine, agrees very closely in chemical composition with butter from cows' milk, the chief difference being that the oleomargarine contains smaller proportions of the peculiar fats, butyrin, etc., which give butter its agreeable flavor. It is made by taking beef fat or lard, extracting part of the stearin, a material which is familiarly known in candles, and adding a small amount of butter to the residue. It is this small quantity of butter which gives the butter-flavor to the whole.

As will be explained when we come to consider the digestibility of foods, the difference in digestibility between butter and oleomargarine is at most too small to be of any considerable consequence for ordinary use. The nutritive values of the two are very nearly the same. In fulfilling one of the most important functions of food, that of supplying heat and muscular energy, butter and oleomargarine excel in efficiency all, or nearly all, of our other common food materials; at least such is the outcome of the best experimental testimony. In appearance and flavor the common kinds of oleomargarine resemble butter so closely that it is difficult even for an expert to distinguish between them.

These butter substitutes are manufactured at very low cost, so that they can be sold at retail at about half the price of butter. They are, therefore, food products of large economic importance and of great benefit to that large class of our population whose limited incomes make good dairy butter a luxury, and, for that matter, to all who need to economize in their living expenses.

Like many other manufactured food products, oleomargarine is liable to be rendered unwholesome by improper materials and methods of manufacture. Butter, likewise, is often improperly made and is liable to become unwholesome. In the considerable mass of evidence which has come under my own observation there is no indication that butter substitutes, as they are actually sold in our markets, average less wholesome or healthful or are in any way less fit for human food than ordinary butter, though some observers in whose judgment I have confidence are inclined to think that on the whole the advantage as regards wholesomeness is somewhat in favor of butter. Among the chemists who are recognized as authorities in these matters, both in this country and in Europe, there is very little difference of opinion as to the value of oleomargarine for food.

There is, however, a popular prejudice against imitation butter which is very unfortunate, especially for people in moderate circumstances and for the poor, whom it is most calculated to benefit. This prejudice, which a new food material very naturally meets, is fostered, and often conscientiously, by representatives of the dairy interest, which fears from imitation butter a damaging competition, though the most accurate statistics show it to be far less serious than is generally believed. On the other hand, the benefit which butter substitutes are calculated to bring is largely prevented, and an immense wrong is done by the very general sale of the imitation under the guise and name and at the price of butter.

In a number of States in which the dairy interests are large, the manufacture and sale of butter substitutes has been prohibited by legislative action. In other States laws have been enacted to regulate their sale and prevent fraud. An attempt was made in Congress to check the manufacture and sale by taxation sufficient to bring their cost nearly up to that of butter. In the law as actually passed, however, the tax was very much reduced, so that while it may help toward preventing improper sale of butter substitutes and, by obliging sellers to pay high license fees, may considerably interfere with their general use, it will not be as effective in excluding them from the markets as was desired.

This is a case where mechanical invention aided by science is enabled to furnish a cheap, wholesome, and nutritious food for the people. Legislation to provide for official inspection of this, as of other food products, and to insure that it shall be sold for what it is and not for what it is not, is very desirable. Every reasonable measure to prevent fraud, here as elsewhere, ought to be welcomed. But the attempt to curtail or suppress the production of a cheap and useful food material by law, lest the profits which a class, the producers of butter, have enjoyed from the manufacture of a costlier article may be diminished, is opposed to the interests of a large body of people, to the spirit of our institutions, and to the plainest dictates of justice.*

In discussing the composition of our foods we must consider not only the quantities of nutritive ingredients which they contain, but also the part each one of these classes of nutrients has to perform in the nourishment of the body, and the proportions which are appropriate for the diet of different persons.

The protein compounds, sometimes called "muscle-formers," are the only ones which contain nitrogen. According to the best experimental evidence they alone form the basis of blood, muscle, tendon, and other nitrogenous tissues of the body. As these tissues are worn out by constant use they are repaired by the protein of the food. The protein, fats, and carbohydrates are all transformed into fat. They all seem to share, therefore, in the formation of the fat of the body. They all likewise serve as fuel to maintain the heat of the body and to yield muscular energy for its work. Late experiments indicate that in those serving as fuel, one part by weight of fats is equivalent to a little over two parts of either protein or of carbohydrates. The mineral matters make up a large part of the bones and teeth, small proportions are contained in the other tissues, and they are necessary for nutrition in various other ways.

It is a fundamental principle of food economy that the diet should contain nutritive material adapted to the wants of the consumer. A great deal of experimenting and observation have been devoted to the determination of the quantities of protein, fats, and carbohydrates needed for the daily nourishment of individuals of different age and sex, at work or at rest, and subject to the varied conditions of life. In Germany, where the subject has been most thoroughly studied, it has come to be commonly accepted that about 4.2 ounces of protein, 2 ounces of fats, and 17.6 ounces of carbohydrates will make a fair daily ration for a laboring man of average weight and doing moderate work. Of course he can get on with less of one if he has more of the others. But there is a minimum below which he cannot go without injury, and his amount of protein should not fall much below the 4.2 ounces per day, though protein, as we shall see later on, is by far the costliest of the nutrients. In animal foods, furthermore, it is usually associated with the so-called extractives, which have a peculiarly agreeable flavor. In accordance with one of those universal processes of natural selection which science is gradually helping us to understand, the food of the poor is apt to contain too little protein and that of the rich too much.

The flesh of codfish contains, aside from water, little else than protein, butter is almost wholly fat, and sugar and starch are carbohydrates. The lean meats are similar to codfish; fat pork resembles butter, and the chief nutrient of potatoes and rice is starch. Each of these materials is unfit by itself for nourishment. Milk, on the other hand, abounds in all the nutrients and is more nearly a "perfect food," for those with whom it agrees, than any other animal food material. While meats and fish are rich in protein, and most meats and some fish abound in fats, the vegetable foods generally lack protein and fats but have an excess of carbohydrates, of which the meats and fish have none. Beans and pease, however, have a good deal of protein.

We have here a very simple chemical explanation of a usage which, under the promptings of experience or instinct, mankind has almost everywhere come to adopt,— that of supplementing wheat and corn and rice and potatoes with meats and fish, or, when these are lacking, by beans, pease, or other vegetables rich in protein. There is a sound reason in the Hindu's practice of eating pulse with rice, in the Irishman's use of skimmed milk with his potatoes, in the Scotchman's

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* The following is from the late report of the Dairy Commissioner of Connecticut, which comes to hand just as this is being written:

"As a protection to consumers the national law is a failure, and the present tax is too small to benefit our dairies to any appreciable extent; a ten cent tax might more nearly have accomplished what the national law was intended to accomplish, but as matters now stand the national law is simply a source of revenue to the national government, and practically levies a tax on poor people who can ill afford to bear it."

partiality for oatmeal, haddock, and herring, and in the frugal New England diet of codfish and potatoes and pork and beans.

Reserving further consideration of these subjects for future articles, I may briefly recapitulate some of the main points already considered.

First. Our bodies and our foods consist of essentially the same kinds of materials.

Second. The actually nutritive ingredients of our food may be divided into four classes: protein, fats, carbohydrates, and mineral matters. Leaving water out of account, lean meat, white of egg, casein (curd) of milk, and gluten of wheat consist mainly of protein compounds. Butter and lard are mostly fats. Sugar and starch are carbohydrates.

Third. The nutrients of animal foods consist mainly of protein and fats. Those of the vegetable foods are largely carbohydrates. The fatter kinds of meat and some species of fish, as salmon, shad, and mackerel, contain considerable quantities of fat. The lean kinds of meat and such fish as cod and haddock contain very little fat. Beans, pease, oatmeal, and some other vegetable foods contain considerable quantities of protein.

Fourth. The different nutrients have different offices to perform in the nutrition of the body. The demands of different people for nourishment vary with age, sex, occupation, and other conditions of life. Health and pecuniary economy alike require that the diet should contain nutrients proportioned to the wants of the user.

W. O. Atwater.

IF.

IF he had known that when her proud fair face
Turned from him calm and slow
Beneath its cold indifference had place
A passionate, deep woe.

If he had known that when her hand lay still,
Pulseless so near his own,
It was because pain's bitter, bitter chill
Changed her to very stone.

If he had known that she had borne so much
For sake of the sweet past,
That mere despair said, "This cold look and touch
Must be the cruel last."

If he had known her eyes so cold and bright,
Watching the sunset's red,
Held back within their deeps of purple light
A storm of tears unshed.

If he had known the keenly barbèd jest
With such hard lightness thrown
Cut through the hot proud heart within her breast
Before it pierced his own.

If she had known that when her calm glance swept
Him as she passed him by
His blood was fire, his pulses madly leapt
Beneath her careless eye.

If she had known that when he touched her hand
And felt it still and cold
There closed round his wrung heart the iron band
Of misery untold.

If she had known that when her laughter rang
In scorn of sweet past days
His very soul shook with a deadly pang
Before her light dispraise.

If she had known that every poisoned dart —
If she had understood
That each sunk to the depths of his man's heart
And drew the burning blood.

If she had known that when in the wide west
The sun sank gold and red
He whispered bitterly, "'Tis like the rest;
The warmth and light have fled."

If she had known the longing and the pain,
If she had only guessed,—
One look — one word — and she perhaps had lain
Silent upon his breast.

If she had known how oft when their eyes met
And his so fiercely shone,
But for man's shame and pride they had been wet —
Ah! if she had but known!

If they had known the wastes lost love must cross,—
The wastes of unlit lands,—
If they had known what seas of salt tears toss
Between the barren strands.

If they had known how lost love prays for death
And makes low, ceaseless moan,
Yet never fails his sad, sweet, wearying breath —
Ah! if they had but known.

Frances Hodgson Burnett.

HOW FOOD NOURISHES THE BODY.

THE CHEMISTRY OF FOODS AND NUTRITION. II.

> "These problems, which are of such great importance for physiology, for medicine, and for social economy, cannot be solved without untiring patience and very considerable means."—*Voit.*

"We eat to live." The eating of bread and meat is a simple matter, but the ways in which the different constituents of the food perform their offices in the maintenance of life are problems as profound as any with which physical science has to deal. The works of nature culminate in man. In his organism her operations are most complex and recondite. The laws which regulate our physical being are discovered but slowly and by the most ingenious and profound research. Those which govern the nutrition of our bodies have been shrouded in mystery which only the investigation of later time has begun to unveil. But, here as elsewhere, the crude and often fantastic theories of the past are being gradually replaced by the more certain knowledge of the present.

In the previous article we noticed the chemical composition of the human body and of the food by which it is nourished. It appeared that our bodies and our food both are composed of the same chemical elements, and that the compounds of these elements which chemical analysis reveals in the food are likewise very similar to the compounds of which our bodies are composed. This, indeed, we should expect from the very fact that the body is made of the food.

The reproduction below of a chart from the previous article of this series describes the principal constituents of our foods. The proportions of the several ingredients in a number of food-materials are shown in Diagram III. of the previous article.

But the food does more than to furnish the material of which the body is built up. As our tissues, muscle and tendon, bone and brain, are continually worn out with work and thought and worry, it is with the ingredients of food that they are repaired, and it is our food that supplies the fuel by whose consumption the heat and strength of the body are maintained.

INGREDIENTS OF FOOD-MATERIALS.

NUTRIENTS AND NON-NUTRIENTS.

Our ordinary food-materials, such as meat, fish, eggs, potatoes, wheat, etc., consist of:

REFUSE: *E. g.*, the bones of meat and fish, shells of eggs, skin of potatoes, and bran of wheat.

EDIBLE PORTION: *E. g.*, the flesh of meat and fish, whites and yolk of eggs, wheat flour.

The edible substance consists of:

WATER,
NUTRITIVE INGREDIENTS OR NUTRIENTS.

The principal kinds of nutrients are:

1. PROTEIN,	3. CARBOHYDRATES,
2. FATS,	4. MINERAL MATTERS.

The water and refuse are called non-nutrients. The water contained in foods and beverages has the same composition and properties as other water, and it is, of course, indispensable for nourishment, but is not a nutrient in the sense in which the word is here used.

CLASSES OF NUTRIENTS.

The following are familiar examples of compounds of each of the four principal classes of nutrients:

PROTEIN	*a* ALBUMINOIDS: *Albumen (white) of eggs; casein (curd) of milk; myosin, the basis of muscle (lean meat); gluten of wheat, etc.* *b* GELATINOIDS: *Collagen of tendons; ossein of bones; which yield gelatin or glue.*
FATS	*E. g., fat of meat; fat (butter) of milk; olive oil; oil of corn, wheat, etc.*
CARBOHYDRATES	*E. g., sugar, starch, cellulose (woody fiber).*
MINERAL MATTERS	*E. g., calcium phosphate, or phosphate of lime; sodium chloride (common salt).*

It is to be especially noted that the protein compounds contain nitrogen, while the fats and carbohydrates have none. Meats and fish contain very small quantities of a class of compounds called "extractives" (the chief ingredients of beef tea and meat extract), which contain nitrogen, and hence are commonly classed with protein. The albuminoids and gelatinoids are sometimes called proteids.

The physiological chemistry of to-day looks upon the body as a sort of machine. Food is the raw material; heat, muscular strength, and other forms of energy are the products. But this does not exactly express the idea; for both the machine and its products come from the transformation of the food, and furthermore, the body is continually consuming not only food but its own substance also, in order to generate heat to keep itself warm, and muscular and intellectual energy to do its own work.

The particular question I wish to speak of now is this: What parts do the several classes of nutrients of food, the protein, fats, carbohydrates, etc., play in the nutrition of the body? Or, to put it in another way, of what constituents of the food are flesh and fat made up, what ones supply us with warmth and muscular strength, and what are the chemical transformations which our nutriment continually undergoes in supplying our bodily wants? These transformations belong to what the physiologists are teaching us to call metabolism. It is a part of this subject of metabolism that we have now to consider.

When we know what are the kinds and amounts of nutritive substances our bodies need and our food-materials contain, then and not till then shall we be able to adjust our diet to the demands of health and purse.

The ways in which the body makes use of its food are found out by experiments made with living animals, with pigeons, geese, rabbits, dogs, sheep, goats, oxen, horses and many others, including men. The experimenting of the last few years, particularly, has been very extensive, and has brought extremely important results. To give a brief account of some of these researches and their principal results as applied to the nutrition of man is the object of this article. Will the reader first permit a few technical statements which seem necessary by way of introduction?

If we could follow the course of a molecule of the protein of the meat we eat from the time when, after being digested, it is taken into the blood, and carried and stored in the arm as muscle and afterwards consumed; if we were gifted with vision acute enough to trace the journeyings and transformations of a particle of the fat of the same meat or of the starch of the bread eaten with it, until it is deposited as fat in the muscle or in adipose tissue, or is disintegrated and united with the oxygen of the inhaled air, yielding warmth or strength, the answer to our questions as to how the different nutrients do their work might be made very plain. But vitally important as these processes are, near as they are to us, parts as they are of us, they have been almost entirely beyond our ken until late experimental research has found a practicable way for learning about them. This way of finding how food is used consists in the comparison of the income with the outgo of the body.

The body creates nothing for itself, either of material or energy; all must come to it from without. Every atom of carbon, hydrogen, phosphorus, or other elements; every molecule of protein, carbohydrates or other compounds of these elements, is brought to the body with the food and drink it consumes and the air it breathes. Like the steam-engine, it simply uses the material supplied to it. Its chemical compounds and its energy are the compounds and the energy of the food transformed.

The science of nutrition as it is taught to-day has this marked peculiarity, that it is a matter of definite quantities of income and expenditure, measured in terms of chemical elements and compounds, and of heat and mechanical energy. It is based upon a kind of chemical book-keeping, and the accuracy of its teaching is, in a certain sense, proportional to the accuracy with which the accounts are kept. The items of the account are obtained from experiments with living organisms, with animals fed upon different food-materials, under circumstances and with appliances which render feasible the accurate measurement of income and outgo.

DAILY INCOME AND EXPENDITURE OF THE BODY.—METABOLISM.

Food, drink, and oxygen of inhaled air constitute the income of the body. Part of this material is transformed into blood, muscle, fat, bone, and other tissues. The rest, together with the materials worn out with use, undergo still further chemical transformations. The compounds thus formed are finally given off from the body and constitute its outgo, or expenditure of material.

A small part of the food passes through the alimentary canal undigested and is excreted by the intestine. The larger part is digested, taken into the blood, and distributed through the body. Some of it is used to build up tissues, as in the case of the growing child; some is used to repair the tissues that are being continually disintegrated; but ultimately the oxygen brought from the air through the lungs unites with the carbon and hydrogen of the food or of the tissues consumed, forming carbonic acid and water, while the nitrogen with part of the carbon and hydrogen forms urea and similar products. The urea and allied compounds escape by way of the kidneys, the carbonic acid is given off by the lungs and skin, and the water by the lungs, skin, and kidneys. So, since tissues are made up of the food, practically all of the digested protein, fats, and carbohydrates finally leave the body as urea, carbonic acid, and water.

Let us take, for instance, the case of an ordinary man, say a mechanic or a day-laborer, doing a fair amount of manual work. Let us suppose him to have a diet of beefsteak, bread, potatoes, butter, and water. To simplify the calculations, we will leave out the tea, coffee, salt, etc., and take enough of the bread and potatoes to make up for the milk, sugar, and other materials which he would ordinarily consume. Such quantities as the following would supply the necessary nutrients for a day:

Beefsteak (lean and free from bone)	8	ounces.
Bread	20	"
Potatoes	30	"
Butter	1	"
Water	37	"
Total food and drink.. (6 pounds)	96	ounces.

With these six pounds of food and drink he would consume about 30 ounces of oxygen from the air inhaled during the twenty-four hours, making a total income not far from 126 ounces, or 7⅞ pounds.

But in our chemical balancing of income and expenditure the calculations are made, not in terms of meat and bread and butter, but of protein, fats, carbohydrates, etc. It may be drawn up as below: I give weights in grams as well as in ounces, since we shall find the grams convenient in subsequent calculations.

The experiments I am about to describe are based upon the principle involved in this supposed case. A large number of most important ones have been performed in Germany, in numerous agricultural experiment stations with animals and, in Munich, with men as well.

EXPERIMENTS FOR STUDYING THE LAWS OF NUTRITION.

THE hurried visitor in Munich, after seeing the treasures of painting and sculpture in the Old and the New Pinakothek and the Glyptothek, is apt to drive to the statue of Bavaria, outside the town. In doing so he will very likely pass a house — it is a square, gray, and somewhat gloomy building just across the street from the Crystal Palace — which to the chemist, the physiologist, the agriculturist, and the student of political and social science is of no little interest, for here lived and labored for many years the great philosopher Liebig, who is, more than any other man, the father of the science we are studying. Going on across the Marien Platz with its quaint Renaissance buildings and out through the Sendlinger gate, he passes along the Findling Strasse. On the right, just beyond the gate, is a brick building which the artistic traveler will not be apt to notice, but which to those interested in our present subject is full of attraction. It is the Physiological Institute of the university. In it are the laboratory and respiration apparatus where Pettenkofer, Voit, and others have conducted some of the most important researches in this department of science. If the reader wished to see how some of the facts of modern science are found out, I should hardly know of a more interesting place to which to take him than this.

Coming in through the hallway, we have, on the right, the apartments of the *Hausmeister*, who is at once the chief janitor and the mechanic of the establishment, and on the left,

ASSUMED DAILY INCOME AND EXPENDITURE OF THE BODY OF AN AVERAGE MAN DOING A MODERATE AMOUNT OF MUSCULAR LABOR.

INCOME.

Materials.		*Weights,* Expressed in ounces.	*Weights,* Expressed in grams.*
Nutrients of food	Protein	.4.2	118
	Fats	2.0	56
	Carbohydrates	17.6	500
	Mineral matters	0.8	24
Water of food and drink		71.4	2024
Oxygen of inhaled air		30.2	855
Total		126.2	3577

OUTGO.

Materials.			*Weights,* Expressed in ounces.	*Weights,* Expressed in grams.*
From digested food and inhaled oxygen	Respiratory products excreted through lungs and skin	Carbonic acid	38.8	1100
		Water	12.7	361
	Excreted by kidneys	Urea, etc	1.2	34
		Mineral matters	0.7	20
Water otherwise excreted			71.4	2024
Undigested matters (water free)			1.4	38
Total			126.2	3577

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* One pound, avoirdupois, 453.6 grams; one ounce, 28.35 grams.

rooms for the assistants and for some of the laboratory work, while a stairway leads to the lecture and apparatus rooms above. A door in front opens into the main working-room, which is fitted up like an ordinary chemical laboratory. At different desks assistants and students are at work, and we perhaps see the burly form of the *Diener*, the laboratory servant, with whom a large number of experiments have been made.

At the left is a room supplied with a number of curious-looking cages. In one may be a dog, in another a goose, and in a third a number of rats, all being used for feeding-trials of one kind or another. In the rear are the balance-room, the study of Professor Voit, director of the establishment, and, what is most interesting of all to us, the respiration apparatus.

Before explaining the respiration experiments, which are somewhat complicated, let me describe a simpler experiment, taking one actually made to study the effect of protein in the form of lean meat, *i. e.*, muscle.

The question was this: From a given quantity of the protein of muscular tissue, how much will be digested by a healthy man, and will the quantity digested suffice to maintain the supply of protein in his body? In other words, will the man gain or lose protein, or will he simply hold his own on this diet?

The subject was a medical student. The experiment lasted three days. For protein he ate very lean beefsteak. This contained, along with the protein, a little fat (the fat was trimmed out as carefully as practicable, but nevertheless minute particles remained about and within the muscular fibers of the meat), and mineral matters, besides, of course, considerable water. The diet consisted of the beefsteak cooked with butter, seasoned with pepper, salt, and Worcestershire sauce, and taken with water, beer, and wine.

Leaving the other materials out of account, as they did not essentially affect the results, the food contained 1200 grams, about 2 pounds 10 ounces, of the lean meat, and 30 grams, or a little over an ounce, of butter per day. The total quantity of nitrogen in the food was about 38 grams daily, of which over 37 grams were digested. It is mainly upon this nitrogen that the experiment hinges.

One of the hard-fought questions of physiological chemistry has been whether or not all of the nitrogen given off from the body (aside from that which is undigested) is excreted by the kidneys. But it is now pretty well settled that this is the only way by which any considerable quantity leaves the body. If then we know how much nitrogen is digested and taken into the circulation and how much is withdrawn in this way, we have an easy means of determining whether the stock of nitrogen in the body is gaining or losing. If I put more money in the bank than I draw out, my balance on the books shows an increased amount to my credit; but if I take out more than I put in, my deposit grows smaller. In like manner the balance of income and outgo of nitrogen shows whether the body is gaining or losing nitrogen.

Now for this purpose we may regard the compounds of the body, exclusive of water and mineral matters, as belonging to two classes — protein compounds and fats. And numerous as the protein compounds are, the proportion of nitrogen is nearly the same in all, and we may take the protein of muscle as representing the whole class. For every gram of nitrogen there will be just about 6¼ grams of protein, and for every gram of protein there will be about 4⅓ grams of muscle, tendon, and the like in meat. Accordingly, for every gram of nitrogen there will be (6¼ x 4⅓) about 27 grams of muscle, exclusive of fat.

The question, then, may be put thus: On the diet of 2 pounds and 10 ounces of lean meat and an ounce of butter per day, was the store of protein in this man's body increased or decreased? In other words, so far as muscular tissue was concerned did he gain or lose or hold his own? Here are the figures:

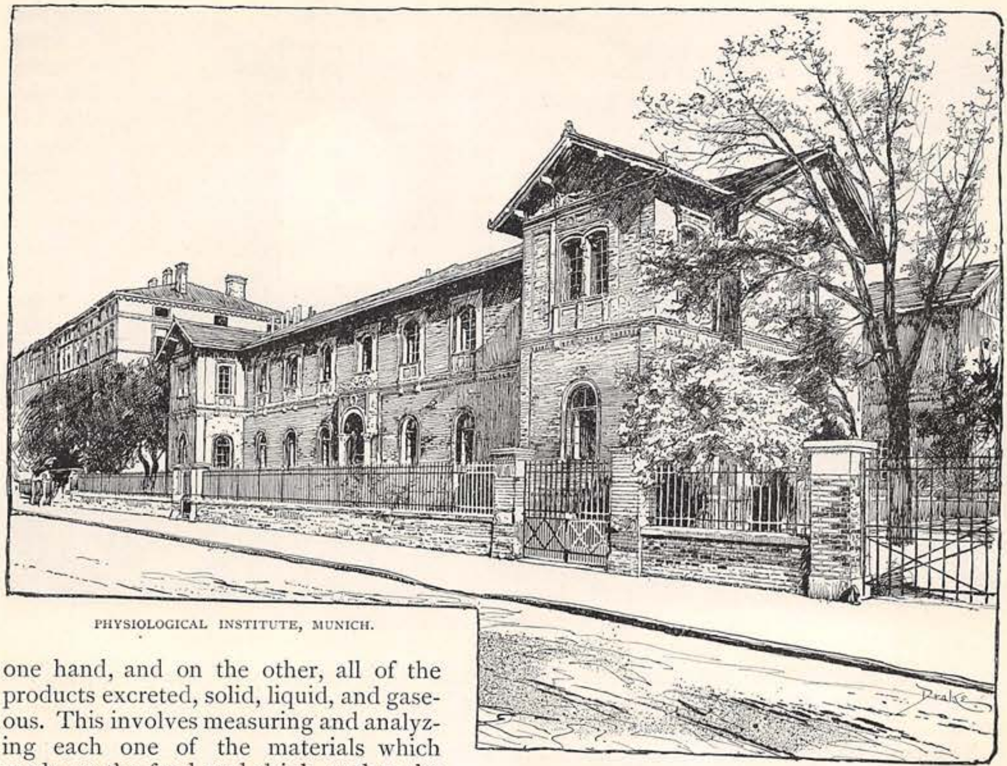
INCOME AND OUTGO OF DIGESTED NITROGEN IN EXPERIMENT WITH A MAN ON DIET OF LEAN MEAT.

Total nitrogen....................	per day	.38.5	grams.
Nitrogen...................kidneys	" "	37.2	"
Balance, stored in the body	" "	1.3	grams.

That is to say, this young, vigorous man, a student, at his ordinary occupations, studying in his room, listening to lectures at the university, working several hours each day in the laboratory, walking a little for exercise, and living on a diet of protein with a very little fat, gained nitrogen at the rate of 1.3 grams per day. These 1.3 grams of nitrogen represented about 8.2 grams of protein or 35 grams (1¼ ounces) of muscle gained per day during the three days of the experiment. In other words, so far as the lean flesh in his body was concerned he just a little more than held his own.

But what about the fat of his body — did he gain or lose? Did the protein and fat of the meat and butter suffice still further to supply him with heat and muscular energy, or did he consume some of the fat previously stored in his body?

The only way to answer the question is to measure exactly all of the income and the outgo of the body — the food and drink on the



PHYSIOLOGICAL INSTITUTE, MUNICH.

one hand, and on the other, all of the products excreted, solid, liquid, and gaseous. This involves measuring and analyzing each one of the materials which made up the food and drink, and at the same time all of the products excreted by the intestines, kidneys, lungs, and skin. In brief, we must, with the rest, measure the compounds given off as vapor or gas. With them, the account of income and outgo will be complete. But this means that we must measure and analyze the inhaled and exhaled air.

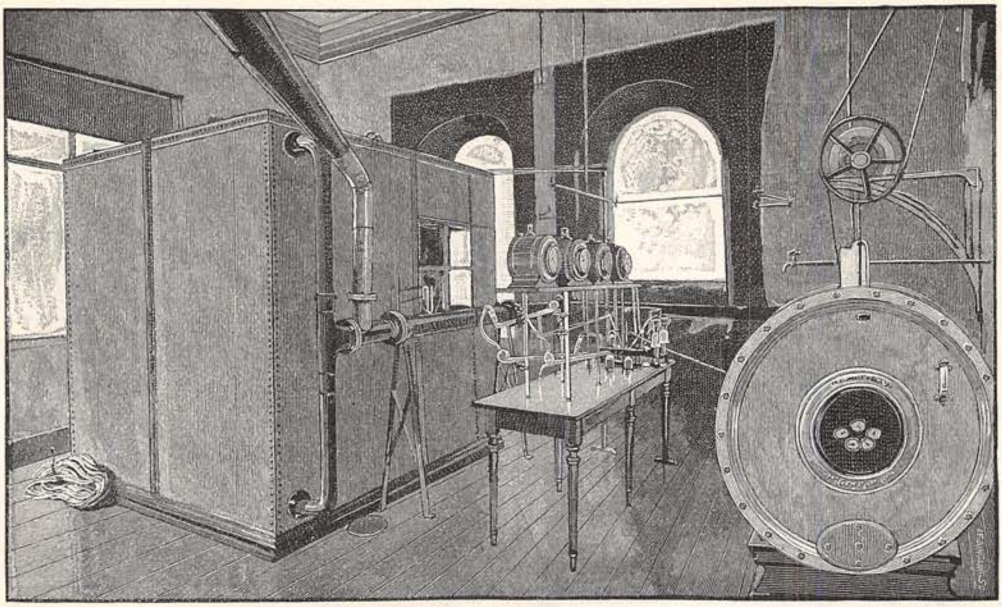
PROFESSOR PETTENKOFER.
(FROM A PHOTOGRAPH BY F. MULLER.)

THE RESPIRATION APPARATUS.

The respiration apparatus is a device for measuring the respiratory products. Many forms have been devised, from one in which the products of respiration of a piece of muscle taken from a just-killed animal can be measured, the respiratory process being maintained by artificial circulation of blood through the muscle, to one in which an ox may be kept for days or weeks, and the composition of the inhaled and exhaled air likewise determined.

A very interesting form is that used by the French experimenters, Regnault and Reiset. This is a small chamber of glass, inside of which the animal is placed, some rather complicated appliances being used to continually renew the supply of oxygen and remove the carbonic acid and other products of respiration. But from insufficient ventilation and other minor difficulties, this form of apparatus has not quite sufficed for satisfactory experiments, especially with the larger animals and with man.

By far the most satisfactory apparatus is that invented by Professor Pettenkofer of Munich. This, to my notion, is one of the most interesting devices of modern experi-

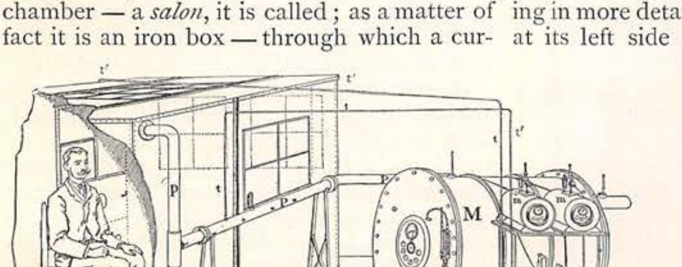


PETTENKOFER'S RESPIRATION APPARATUS.

mental science. The first one was built through the munificence of the King of Bavaria.

The peculiar features of this apparatus are that the subject of experiment, be it a dog, an ox, or a man, is in a comfortable, well-ventilated room, and that the air, which passes through it in a continuous current, is measured and is analyzed both before it goes in and after it comes out. We can thus tell just what the animal has added to it, in other words, what material has been given off as gas or vapor from the body. The arrangements do not provide for estimating all the respiratory products with absolute exactness, but they suffice for reasonably accurate results. The form used for experiments with man consists of a chamber — a *salon*, it is called; as a matter of fact it is an iron box — through which a current of air is drawn by a large pump, the latter being worked by an engine.

The *salon* of the large apparatus at Munich is made of plates of iron, similar to boiler-iron, and is in the form of a cube about eight feet each way. It has glass windows, and a door large enough to admit a man. The large engraving herewith shows the apparatus as it is now arranged. On the left is the chamber in which the man under experiment stays; near are a table holding apparatus for analyzing the air before and after it passes through the chamber, and a large meter for measuring the quantity of air which passes through. In an adjoining room is the machinery by which the current of air is pumped through the apparatus. The smaller sketch explains the working in more detail. The air enters the chamber at its left side and passes out on the right through the large pipe P P, into the large meter M, in which it is measured. A small tube, t t, takes from the pipe P P a portion of the air which has been passed through the chamber and contains the products of respiration into two small meters, m m, where it is measured, and through the apparatus on the table T, where it is analyzed. A similar small tube, t′ t′, brings air for analysis from the outside of the apparatus, taking it from the left of the chamber



DETAIL DRAWING OF ABOVE.

where it enters the latter and carrying it into two other small meters (not shown in this sketch), where it is measured, and through apparatus, also not shown here, by which it is analyzed. In the larger engraving the four small meters and apparatus for analyzing the air are shown on the table between the chamber and the large meter. Comparisons of the quantity and composition of the air which has passed through the chamber with the outside air show what the man has imparted to the air in breathing, and thus tell the amounts of the products of respiration. The food and drink and the solid and the liquid products of its consumption in the body are at the same time measured, weighed, and analyzed, and thus all of the items of income and outgo of the body are determined.

The first man to enter the respiration apparatus for experiments upon himself, I believe, was Professor Ranke of Munich, who has described his experiences in his book on "The Nutrition of Man" ("Die Ernährung des Menschen"), as well as in special memoirs. He tells us that in trials in which he took no food the fasting was somewhat disagreeable, but far less painful than many would think. "I found myself at the end of the first 24 hours entirely well; at the end of the second 24 hours without food or drink, during which sleep had been disturbed, the head was somewhat heavy and there was an oppressiveness in the stomach and considerable weakness; but the sensation of hunger, . . . which was strongest about 30 hours after the last food was taken, . . . did not appear any more."

In the greater number of Professor Ranke's experiments he took a reasonable amount of food. The diet was simple, and consisted of such materials as lean meat, bread, white of egg, starch, sugar, butter, etc., and was found to serve the purpose very well. After some experience a ration was arranged which corresponded very well in composition with that used by ordinary working people, and was at the same time not at all unacceptable. When a number of experiments with Professor Ranke had been completed, several series were made with other persons. One of these latter series I will briefly describe.

The subject was a strong, healthy mechanic, a watchmaker, 28 years old and weighing about 156 pounds. Three experiments were made, each occupying 24 hours. In the first, the man took nothing but a little meat extract, salt, and water, and did no work. In the second, he had a liberal allowance of palatable food, but still remained at rest. In the third, he had the same diet as in the second, but worked hard at turning a lathe for nine hours, so that he was thoroughly tired at night. During the daytime of the first two experiments, I should say, he read, cleaned a watch, and otherwise occupied himself to while away the time, making, however, very little muscular effort.

PROFESSOR VOIT. (FROM A PHOTOGRAPH BY F. MULLER.)

The three experiments, then, show the effects of fasting and rest, food and rest, and food and muscular exercise upon the income and outgo of this man's body. We will note only very briefly some of the details of the experiments, the full accounts of which fill many pages.

The diet of the first experiment consisted of:

Meat extract, 12.5 grams (a little less than one-half ounce).
Salt, 15.1 grams (a little over one-half ounce).
Water, 1027.2 grams (about a quart).

The day's ration of the second trial included a third of a pound of lean meat, a pound of bread, a little over a pint of milk, and about a quart of beer, and other materials as follows:

DAY'S FOOD IN SECOND EXPERIMENT.

Meat, lean beef...........	140	grams.
Egg albumen (white of egg)	42	"
Bread....................	450	"
Milk......	500	"
Beer.....................	1025	"
Lard	70	"
Butter...................	30	"
Starch.	70	"
Sugar...........	17	"
Salt.....................	4	"
Water	286	"

The diet of the third experiment was essentially the same as that of the second, except that the man drank a little more water.

The income included, besides the food and drink, the oxygen consumed from the inhaled air. The estimated quantities were :

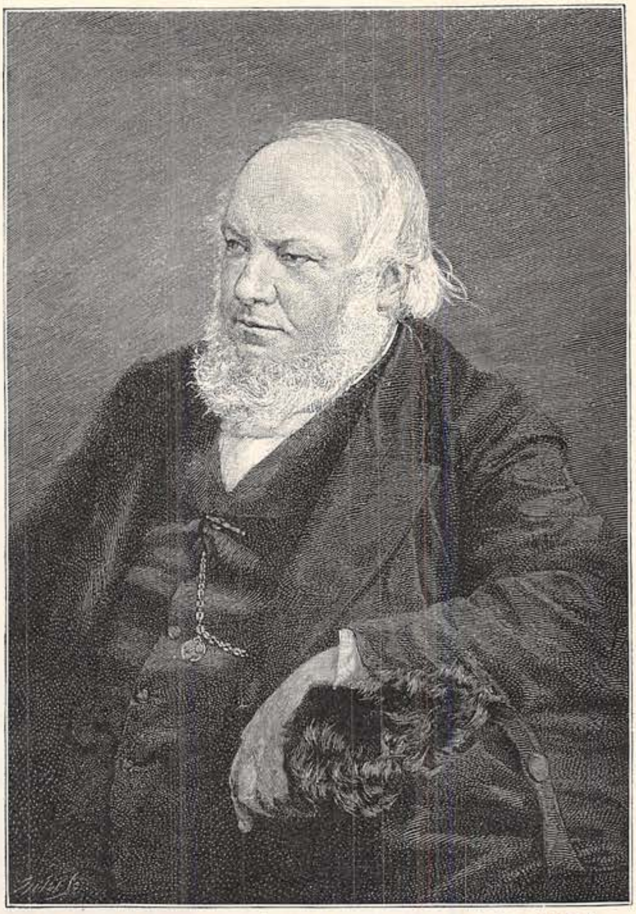
Oxygen used in 24 Hours.

First experiment, fasting and at rest, 779 grams.
Second experiment, liberal ration and at rest, 709 grams.
Third experiment, liberal ration and at work, 1006 grams.

The final balance-sheets of the experiments, which show the details of income and outgo in terms of the chemical elements, carbon, nitrogen, etc., are too extensive to be reported here. That for each experiment would nearly fill one of these pages, but as some readers may be curious to see what they are, I give the principal data in abbreviated form.*

DAILY INCOME AND EXPENDITURE OF CHEMICAL ELEMENTS.

	Carbon.	*Hydrogen.*	*Nitrogen.*	*Oxygen.*
Experiment with no food (except meat extract) and no work:	*Grams.*	*Grams.*	*Grams.*	*Grams.*
Income	2.4	115.1	1.2	1698.4
Outgo	209.5	221.6	12.5	2301.4
Loss	207.1	106.5	11.3	603.0
Experiment with liberal ration of meat, milk, bread, etc., and no work:				
Income	315.5	270.9	19.5	2712.9
Outgo	275.7	248.2	19.5	2630.2
Gain..........	39.8	22.7	0.0	82.7
Experiment with liberal ration, as in preceding experiment, and hard work:				
Income	309.2	297.7	19.5	3232.5
Outgo	336.3	304.9	19.5	3246.5
Loss.......	27.1	7.2	0.0	14.0


PROFESSOR MOLESCHOTT. (FROM A PHOTOGRAPH BY C. LE LIEURE.)

But we wish to know what quantities of flesh and fat the man gained or lost under these different conditions of food and fasting, labor and rest. The figures just cited are for the chemical elements of which the protein and fats are composed. Knowing the propor-

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* The accuracy of these experiments has been occasionally called in question, especially on the ground that with the possible sources of error, so complete an accuracy in the balance-sheet is in itself suspicious.

That some of the chemical work involved in the researches of which these form a part might have been performed by more nearly perfect methods is doubtless true, but I believe that experience in the Munich laboratory and careful examination of the published details of the researches must convince the most exacting physiological chemist that such criticisms are without foundation. As regards the chief subject of criticism, which is connected with the question of "nitrogen balance," it will suffice to say that the tendency of the latest investigations has been to very decidedly confirm the correctness of the assumption on which the Munich results are based, *i. e.*, that practically all the digested nitrogen is excreted by the kidneys. And certainly all the men I have known among those who have worked in the Munich laboratory regard the complete accuracy above alluded to as the result of careful and thoroughly reliable work.

tions of the elements in each compound, it is easy, from the figures for the elements, to estimate the quantities of the compounds. Omitting details of the calculations[*] the results are given in the balance-sheet of compounds herewith. Regarding the carbohydrates, however, I should explain that since the body has extremely little of its own, and those of the food are consumed, they are left out of account in the experiment without food, and the amounts received and consumed in the experiments with food are taken as balancing one another.

INCOME AND EXPENDITURE OF CHEMICAL COMPOUNDS BY BODY OF MAN.

	Fasting. No work.			*Liberal ration. No work.*			*Liberal ration. Hard work.*		
	Protein.	*Fats.*	*Carbohydrates.*	*Protein.*	*Fats.*	*Carbohydrates.*	*Protein.*	*Fats.*	*Carbohydrates.*
	Grams.	*Grams.*	*Grams.*	*Grams.*	*Grams.*	*Grams.*	*Grams.*	*Grams.*	*Grams.*
Income	7	0	none	122	117	332	122	117	352
Outgo.....................	78	216	none	122	52	332	122	173	352
Gain, + or loss —	—71	—216	none	0	+65	0	0	—56	0

The protein gained or lost was mainly from the muscles and similar tissues, or what we may call flesh as distinguished from fat. Taking the figures for protein and fats gained and lost as shown in the last line of the balance-sheet of income and expenditure of compounds, changing grams to ounces, and assuming that with each ounce of protein would be water, etc., enough to make the equivalent of 4⅓ ounces of lean flesh, *i. e.*, muscle, tendon, etc., we have this final result of the trials; the quantities, as before, are those gained or lost in one day:

OUTCOME OF THE EXPERIMENTS AS REGARDS INCREASE OR DECREASE OF LEAN FLESH AND FAT WITHIN THE BODY.

	Lean flesh (muscle, etc.).	*Fats.*
No food, no work, loss..........	11 ounces	7⅔ ounces
Liberal diet, no work, gain......	none	2⅓ "
Liberal diet, hard work, loss.....	none	2 "

That is to say, fasting, and without muscular labor, the man lived upon the tissues of his body, and consumed daily a trifle less than three-quarters of a pound of muscle, and with this nearly half a pound of the fat previously stored in his body. With plenty of food, and still resting, he neither gained nor lost lean flesh, but gained 2⅓ ounces of fat in a day. And when he set himself to hard muscular work, with the same amount of food, he likewise held his own so far as lean flesh was concerned, but lost two ounces of fat. The body used for its support protein and fats, in each case, and carbohydrates when it had them. When the nutrients were not supplied in food, it consumed a little protein and a good deal more fat from its own store. With a ration which sufficed to exactly maintain its protein without gain or loss, the body gained fat when it had only a little more than its own muscular work to perform (that included in breathing, keeping the blood in circulation, etc.), and lost fat again when this work was increased by manual labor.

If we had only these experiments to judge from, we might infer that muscular energy comes from consumption of fat, and that the special work of the protein of the food is to repair the wastes and make up for the wear and tear of the protein of the body; and this would be true as far as it goes. But, of course, many other experiments and of many different kinds are needed to settle these questions. The majority of the most useful ones, thus far, have been made with other animals than man. For experiments with dogs, geese, and other small animals a small respiration apparatus on the plan of Professor Pettenkofer's has been devised by Professor Voit.

In studying the laws of animal nutrition the most convenient organism, for many purposes, is that of the dog. The dog thrives upon both animal and vegetable foods, utilizes large quantities of food to advantage or endures long fasting with patience, and makes ready responses by changes of bodily condition to changes in the food. In reading the accounts of the famous feeding-trials conducted by Bischoff and Voit, one is surprised to see what control they obtained of the organisms of the dogs experimented with. By altering the kinds and quantities of food constituents, Voit was able either to reduce both the flesh (protein) and the fat of the animal's body or to increase

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[*] The calculations, based upon accepted principles of physiological chemistry, are too complex for this place. They are to be explained in detail in a book on this general subject now in preparation. Students may find them in the original (German) memoirs in which the experiments are described.

both flesh and fat, or to reduce the one or to increase the other. Indeed, the manipulations effected in this way seemed almost equivalent to getting into the tissues and directly removing or adding flesh, or fat, at will. The principles thus learned from experiments with the dog and other animals apply in the main, though not in all the details, to the nutrition of man.

But I must beware of burdening the reader with details, a danger he will appreciate when I say that the experiments of the last twenty years are numbered by hundreds and even thousands, and that the literature of the subject is so voluminous that few specialists even are able to handle it. I will endeavor to very briefly summarize a few of the main results. I do not know how to do this better than in the following chart, which was prepared for the Food Collection of the National Museum.

USES OF FOOD IN THE BODY.

Food supplies the wants of the body in several ways. Food furnishes:

1. The material of which the body is made.
2. The material to repair the wastes of the body, and to protect its tissues from being unduly consumed.

Food is consumed as fuel in the body to:

3. Produce heat to keep it warm.
4. Produce muscular and intellectual energy for the work it has to do.

The body is built up and its wastes are repaired by the nutrients. The nutrients also serve as fuel to warm the body and supply it with strength.

WAYS IN WHICH THE NUTRIENTS ARE USED IN THE BODY.

The Protein of food	forms the nitrogenous basis of blood, muscle, sinew, bone, skin, etc. is changed into fats and carbohydrates. is consumed for fuel.
The Fats of food	are stored in the body as fat. are consumed for fuel.
The Carbohydrates of food	are changed into fat. are consumed for fuel.
The Mineral matters of food	are transformed into the mineral matters of bone and other tissues. are used in various other ways.

Like all attempts to tell a long story in a few words, it omits many important details and gives incomplete expression to the facts which it states. Thus, regarding the use of the nutrients as "fuel," although their elements combine with oxygen as those of the coal and wood do in the stove, the process, as it actually goes on in the body, is far more complex and less completely understood. In saying that food yields muscular and intellectual energy the statements do not explain how this is done, nor has science yet given an at all complete explanation of these wonderful phenomena. Nor do these statements include the important fact that the fats, protein, and other substances stored in the body are used like those of the food. But the chart includes what it is most important for our present purpose to remember, and we shall have occasion to make further explanations in another place.

Translating the statements of this chart into ordinary language, it means that, when we eat meat and bread and potatoes and other kinds of food, our bodies use the nutritive ingredients in different ways. Thus the myosin, which is the principal nutritive ingredient of muscle (lean meat), the casein (curd) of milk, the albumen (white) of egg, and the gluten of bread are all albuminoids or protein compounds, and are transformed into muscle, tendon, and other nitrogenous materials in our bodies. The protein compounds are sometimes called flesh-formers, which is all very well so far as it goes, but does not go far enough. They, and they alone, form flesh (*i. e.*, nitrogenous tissue), it is true, but they do a good deal more. They are also transformed into fat and carbohydrates in our bodies, and they are consumed as fuel to yield us heat and muscular strength.

But our meat always contains more or less fat. This may be taken up by the body and stored as fat within the muscle, bone, and adipose or other tissues, and so retained for a time as a part of the body-fat; but the bulk of the fat of the food serves as fuel, and that which has been stored in the body is consumed for the same purpose when occasion demands. Thus the man in the experiments above described lived on the fat previously stored in his body when he took no food; laid up fat when he had a liberal ration and did no work; and drew upon the accumulated store again when he did hard muscular work with the same ration. The fat of milk, of butter, and of the fatty and oily materials in bread, corn meal, and other foods is like that of meat, stored as body-fat and used for fuel.

Vegetable foods, such as flour, meal, potatoes, and the like, contain a great deal of starch, sugar, and other carbohydrates. When these are taken into the body they are to some extent converted into fats, but their main use seems to be to serve for fuel. In serving as fuel the carbohydrates protect the fats and protein from being consumed. In like manner the fats may protect protein from consumption.

In short, the nitrogenous compounds of muscle, tendon, bone, and other parts of the framework of the body and of the blood are made of the protein of the food. We get the fat of our bodies not only from the fats but from the protein, and probably from the carbohydrates, starch, sugar, etc., of our food. Other animals, dogs, sheep, swine, and geese, transform carbohydrates into fats, and there is every reason to believe that man is endowed with the same faculty. We use all these classes of nutrients, protein, fats, and carbohydrates, as sources of warmth and muscular strength. Our bodies, when they are in a healthy condition, contain a reserve of protein and fat which is drawn upon if food is lacking, or if there is extra muscular work to be done or extra cold to be endured. And whether the food supply is rightly adapted to the demands of the body or not, its tissues are continually consumed to supply its wants and are as constantly rebuilt from the food. The old notion that the whole body is made over once in seven years is wrong, however. Some parts are used up and renewed very rapidly, others very slowly. Such, at any rate, are the teachings of the most careful research as they are understood by the investigators who seem best qualified to judge.

ADAPTATION OF THE DIET TO THE DEMANDS OF THE BODY.

THE further details of the ways in which food is used in nutrition will naturally come in with the explanations in succeeding articles. But there are one or two more points which perhaps I ought to speak of now. One is, that the body requires a proper supply of each of the different kinds of nutrients for healthful nourishment. The proper supply of neither can be cut off without injury.

The protein can, to be sure, do some of the work of the fats and the carbohydrates. In the lack of plenty of vegetable food to furnish starch and sugar, for instance, we may get on pretty well for a while with meat, which has no carbohydrates, the protein and fat of the meat taking their place as fuel. The Laplanders and Esquimaux have extremely little vegetable food and consume enormous quantities of meat, and especially of fat meat, blubber, and what not. But their diet is hardly adapted to either the wants or the digestive apparatus of people of temperate climates. Ordinary people need considerable carbohydrates, and no amount of protein can fully supply their place.

But while the protein can to some extent serve in place of the carbohydrates and fats, these latter cannot replace the protein. The Esquimaux can live on meat, but neither men nor other animals can long thrive upon a diet of fat, or sugar, or starch without protein. The reason is that protein has a kind of work to do in building up the muscle, tendon, and other tissues which the fats and carbohydrates cannot perform. Hence, we must have a certain amount of protein in our food or our bodies will suffer for the lack of it, and the more work there is to do, the greater the wear and tear of muscle and tendon, the more liberal must be the supply of protein as well as of other nutrients.

The effect of one-sided diet is very well illustrated in some experiments by Professor Ranke. They were made in the respiration apparatus at Munich, and belonged to the series of which I have already spoken. After he had studied the changes that went on in his body when fasting, he proposed to himself these questions:

What will be the effect of a diet of protein with very little fat and no carbohydrates on the one hand, and of a diet of fats and carbohydrates without protein on the other? In other words, how will the composition of the body be affected by food rich in protein and containing little else, and how will the store of fat and protein be altered by leaving the protein out of the food and living on the other nutrients?

For the diet of protein, he took lean meat, with butter and a little salt, essentially the same diet as was used by the student in the experiment described above. He had found himself able to eat 2000 grams of the lean meat in the course of the day, but in this experiment, which lasted 24 hours, he ate only 1833 grams (about 4 pounds) of meat and with it 70 grams of fat, 30 grams of salt, and 3371 grams (nearly 3 quarts) of water. Without going into the details, suffice it to say, that, according to Professor Ranke's calculations, his body lost 15.1 grams of fat and at the same time gained 113 grams of protein during the day of the experiment. In the other experiment, which likewise continued for 24 hours, the food consisted of 150 grams of fat, 300 grams of starch, and 100 grams of sugar, an even less appetizing mixture perhaps than the lean meat and butter for an exclusive diet, but yet one which, if put together with proper culinary skill, makes a cake that can be swallowed. This time he lost 51 grams of protein and gained 91.5 grams of fat.

The results of these two experiments may be recapitulated thus:

On the diet consisting chiefly of	The body
Protein (lean meat, etc.),	gained protein (muscle, etc.) and lost fat.
Fats and carbohydrates (starch and sugar),	lost protein and gained fat.

This is just what we might expect. But it is interesting to have the facts and figures to show exactly what did take place, and other experiments make it safe to say that if either the quantities of food or the condition of Professor Ranke's body had been different, the results would have been different also. Thus in the first experiment if he had eaten less meat he would have stored less protein; indeed, with a small enough ration he would have lost both protein and fat, and it seems probable that if he had not been a rather fat person he would not have lost fat so readily on the protein diet.

Experiments confirm and to some extent explain the fact so well attested by general experience, that a mixed diet is best for ordinary people in health. Professor Ranke found that when he did no muscular labor, his body neither gained nor lost; that, in other words, he just about "held his own" with food, containing per day:

Protein.	*Fats.*	*Carbohydrates.*
100 grams (3.5 oz.)	100 grams	240 grams (8.5 oz.)

Professor Voit estimates as a fair allowance for a laboring-man doing a moderate amount of muscular work:

Protein.	*Fats.*	*Carbohydrates.*
118 grams (4.2 oz.)	56 grams (2 oz.)	500 grams (17.6 oz.)

For reasons to be given later, I think that to fairly meet the demand of the average American laboring-man (I mean the man whose labor is done with his muscles; brain-workers who have little muscular exercise need less food, I suppose) a more liberal allowance than Voit makes for laboring-men in Germany is needed. The American "working-man" is better paid, has more and better food, and does more work than his European brother. I should be inclined to quantities more like the following for the nutrients in the daily food of an average man doing manual work:

	Protein.	*Fats.*	*Carbohydrates.*
For moderate work	125 grs. (4.4 oz).	125 grs.	400 grs. (14.4 oz).
For hard work	150 grs. (5.2 oz).	150 grs.	400 grs.

Men at very severe work may often need much more than the most liberal of these rations allows, while men, and especially women, of sedentary habits and elderly people are believed to usually require considerably less than the smallest figures indicate.

Statistics collected in the United States imply that the quantity of food consumed by many people whose occupations involve only light muscular labor approaches very near to the largest of these standards, and often considerably exceeds it. Indeed, a large array of facts lately gathered very strongly support the teaching of physicians that the failure to fit the food to the demands of the body, and especially the excessive consumption of certain kinds of food, are the sources of untold injury to health and happiness. But I am getting ahead of my subject.

THE COST AND VALUE OF ABSTRACT RESEARCH.

ONE can hardly realize, until he has found out by personal experience, the amount of labor, care, and patience, as well as learning and skill, that are required for such investigations as these I have described.

Professor Voit tells us that he has often worked with a servant three or four hours each day during an experiment in simply preparing the meat to be used for the food, in freeing it from fat and connective tissues so as to have as nearly pure protein as possible. In describing a series of experiments he says, "We give only the more important observations, in order to enable the reader to judge of the correctness of our conclusions, and omit the details of the analyses, which would swell the article too much." The article fills 115 royal octavo pages and is only one of scores by this one experimenter and his immediate associates.

At the agricultural experiment station at Weende, Germany, where the celebrated feeding-trials by Henneberg, Stohmann, and others with domestic animals were conducted, one of the assistants once told me a bit of experience with the respiration apparatus. As the result of a long series of observations, it appeared that something was out of order. What the trouble was Professor Henneberg could not find out. One day he happened to hear some one speak of the loss of weight of coal when exposed to the air. It occurred to him that a little coal-tar or some similar material, I have forgotten exactly what it was, had been used in the interior of the apparatus, and that perhaps this, like coal, might undergo such chemical changes as to develop gases and cause the trouble. This proved to be the case. The gentleman who related the incident added, "We have been at work now six years with the respiration apparatus and think we have just got where we can obtain satisfactory results with it." There is a popular idea that the results of scientific discovery, at least such as are most useful to people at large, can be turned out like pig-iron or cotton cloth,— so much in a given time, and with no great labor. Nothing could be more contrary to the facts.

To many people, a large part of the research made in the lines of which I have been speaking would appear so abstract and theoretical as to have but very little "practical" use. But as a matter of fact, the very things that seem most abtruse are of fundamental importance in the solution of the weightiest problems of chemistry, physiology, hygiene, and social science. In this practical, pushing country of ours, especially, the idea is current that the profoundest studies, whether in physical science or in other departments of human knowledge, are very appropriate and ornamental for philosophers and for institutions devoted to abstract research, but not of much account for ordinary use. Coupled with this is the notion that our higher educational institutions should be places for the teaching of things already known, and that it is not particularly necessary for them to engage in the discovery of new truth. The more rapidly these impressions are done away with, and the more generally and generously abstract research in all departments of knowledge is cultivated, the better it will be for our thought and for our morals, and the sooner shall we get the information that will most help common folks in the ordinary struggles of daily life.

Is it not a significant fact that when we come to the study of even so preëminently plain and practical a subject as the food question, one which affects as many people, and affects them as seriously in health and purse if not in morals, as any of the great problems that are agitating the thought of the time, we must seek the fundamental data of our studies in the learned and profound research of foreign universities?

THE SOURCES OF INTELLECTUAL ENERGY.—PHOSPHORUS AND THOUGHT.—FISH AS BRAIN-FOOD.

THAT the labor of the brain is just as dependent upon food and the substances formed from it in the body as the labor of the hands, there is hardly room for doubt, but just what chemical elements or compounds, if any, are more concerned than others in mental or nervous exercise is a problem yet unsolved.

A great many people have the idea that thought is especially dependent upon phosphorus, and coupled with this is the widespread belief that the flesh of fish is particularly rich in phosphorus, and is hence especially valuable for brain-food.

The theory that connects thought with phosphorus more than with other elements appears to rest upon the fact that certain compounds, protagon, lecithin, etc., which contain phosphorus and are called phosphorized fats, are more abundant in the brain and nerves than in other parts of the body. From this it has been inferred that mental effort and nervous excitement involve the using up of large amounts of these substances, and that hence phosphorus compounds ought to be especially good for people who have much intellectual work to do or are subject to great nervous strain. In support of this it has been claimed that brain-work increases the amount of phosphorus used up in the body and given off by it, just as muscular work increases the quantity of carbon burned and excreted.

But the compounds that make up the brain and nerves consist of the same elements as those in other organs, though the proportions are different; the phosphorized fats occur in other parts of the body as well as in the brain; cerebrin, a compound especially characteristic of the brain, contains no phosphorus; and the most careful experimenting has thus far failed to establish any definite connection between the amounts of intellectual work done and phosphorus excreted.

The value of phosphorus as food for the brain and nerves is frequently and strongly advocated in advertisements of medicines and medicinal foods containing it, and these are largely prescribed by the most eminent members of the medical profession, whose wisdom in so doing I by no means presume to question. But the theory that phosphorus has more to do, or is more necessary than carbon or nitrogen or other elements, in the production of intellectual energy is one to which I have never heard a physiological chemist of repute express his adherence, and in the writings of the experimental physiologists whose opinions are most valued by their fellow-specialists it is conspicuous by its absence.

The history of the theories of the connection between phosphorus and thought and of the value of fish as food for the brain has some rather curious phases.

Few utterances of modern writers have had such a world-wide currency as the expression, "Ohne Phosphor kein Gedanke" ("Without phosphorus, no thought"). One meets it everywhere and with it the notion, though generally in very crude form, that thought is somehow produced by phosphorus. A German gentleman of great intelligence told me he had often seen people who supposed that thought was accompanied by something in the brain akin to phosphorescence, like the glow of a phosphorus match in the dark. I have been led to think that the phrase has done more than anything else to spread the idea, though the idea could hardly have become so prevalent if there were not something to nourish it. What that something is I do not know, unless it be the natural query in every mind which the theory seems to answer. The expression has been attributed to various authors. An article in the last edition of the "Encyclopedia Britannica" credits it to Büchner. It is due, I believe, to Moleschott, and occurs in his "Lehre der Nahrungsmittel" ("Doctrine of Foods").

Of the early leaders of the movement which is sometimes called Materialism and which has so greatly influenced the thought of our time, Moleschott, Vogt, and Büchner were among the most prominent. Forty years or so ago, Moleschott was a *privat docent*—tutor, we should call it—in the University of Heidelberg, and an aspirant for higher academical honors. He was a man of ability as an investigator and writer. His genius was manifested in a controversy with Liebig in which he gained no little repute, and in other writings in which his views were set forth not only with remarkable force, but in a way which was particularly irritating to the metaphysicians and especially to the theologians of the more orthodox way of thinking. Heidelberg at that time was not so liberal in its theology as it has since become, and — I give the account as it was given me by one of the professors now there — young Moleschott's heterodoxy sufficed to deprive him of the liberty of teaching in the university and, as a not unnatural consequence, obtained for him a call to a professorship in another university, that of Zurich in Switzerland. In course of time he was called to Italy, where, as Professor of Physiology in the University of Turin, and later in the University of Rome, he has achieved still greater fame in science, and has also played an important rôle in statesmanship, both as the holder of a ministerial portfolio and as senator of Italy.

I remember very well a remark regarding his famous expression just referred to, which was made to me by Professor Moleschott in the course of a conversation not many years ago. It accords so well with what he had said in print that I think it will be no breach of confidence to mention it here. Remembering the suggestion of another well-known physiologist, that he had used it simply to illustrate and give point to the doctrine that thought and other mental operations are a function of matter, and thus stir up his ultra-conservative opponents, excite discussion, and propagate his tenets, I asked him what led him to make the statement in that form. He replied that of course he did not mean that intellectual energy was specifically dependent upon the consumption of phosphorus (indeed, that was clearly set forth in his writings at the time), and added with a smile, "Did you ever read ——?" referring to an Italian book on the use of language. I was forced to confess that I had not, to which he replied, "There is a great deal in the way of putting things."

The saying served its purpose wonderfully even if, in its circulation, a shade of meaning has been added to it which it was not intended to convey. Not every man can penetrate to the depths of human sentiment and coin from the common thought that is gathered there a phrase which will pass current everywhere and carry a doctrine with it. Like Grant's "Let us have peace" and Napoleon's "Providence is on the side of the strongest battalions," Moleschott's "Ohne Phosphor kein Gedanke" was a scintillation of genius.

If a current story is true, the idea that fish is especially good for brain-food can be traced to the elder Agassiz, though, for aught I know, it may be older. The story is that, years ago, Agassiz, who was then in the zenith of his fame and whose persuasive skill was scarcely inferior to his scientific genius, made an address in Massachusetts in behalf of a fish commission, and, with other considerations in its favor, urged that fish was very valuable for brain-food and that fish culture was hence peculiarly demanded by the marked intellectual activity of the people of that State. It would be superfluous to add that since that time fish culture has not languished in Massachusetts.

A gentleman well known in American science tells me that he once asked Agassiz what led him to this idea about fish as food, and that he replied, "Dumas [the French chemist] once suggested to me that fish contained considerable phosphorus and might on that account be especially good for food, and you know the old saying, 'Without phosphorus, no thought.' I simply put the two together."

Later, Mark Twain took up the idea and expressed it as follows (in "The Galaxy"):

> "Young Author.—'Yes, Agassiz *does* recommend authors to eat fish, because the phosphorus in it makes brains. So far you are correct. But I cannot help you to a decision about the amount you need to eat—at least, with certainty. If the specimen composition you send is about your fair, usual average, I should judge that perhaps a couple of whales would be all you would want for the present. Not the largest kind, but simply good middling-sized whales.'"

As a vehicle for carrying the idea everywhere and "keeping it before the people" the efficiency of Mark Twain's joke was superlative. And aside from the intrinsic self-propagating power of the combination of joke and theory there was the widespread notion that phosphorus is the thought-producing element to help it. It would be hard to find conditions more favorable for the spread of a theory than were thus provided for this one of fish as nutriment for the brain. Coupled with the notion that phosphorus is the specific thought-element, it has coursed around the world.

Mr. E. G. Blackford, Fish Commissioner of New York and, I understand, the largest dealer in fish on this side of the Atlantic, assures me of his belief that the theory materially increases the demand for fish as food. I have heard the same from other fish dealers, who say, "Why, you know fish is good brain-food." Indeed, it is really amusing, if one takes the trouble to notice, how many people will use the same expression, or one very much like it, if the subject is suggested. The theory is squarely adopted by some very prominent writers on foods, and is sometimes taught in schools. The Rev. Ram Chandra Bose, well known in Europe and America as one of the most learned of the Hindu converts to Christianity, tells me that if one were to "visit any of the great colleges in Calcutta and put to its advanced pupils the question, 'Why are the Bengalese intellectually superior to the other races of India?' the reply would be, 'Because they eat fish.' The belief that fish is rich in phosphorus, and hence serves to strengthen the brain more than other kinds of food do, is current among educated natives and their English teachers."

Even if fish were richer in phosphorus than meats or other food-materials this would not establish its superiority for the nutrition of the brain or the production of intellectual energy. But there is no proof of any especial abundance of phosphorus in fish. On the contrary, an extended series of analyses in this laboratory have revealed proportions of phosphorus in the flesh of our ordinary food fishes differing in no important degree from those which have been found to occur in the flesh of the other animals used for the food of man.

Perhaps some of the readers of this will put me down for an iconoclast, as did a most highly esteemed friend, who bade me, and with all candor and seriousness, to beware of thus ruthlessly attempting to uproot an old and important belief. But possibly they will have the charity to leave me a humble place in their consideration if I add that there is, after all, a way in which fish may make a very useful part of the diet of brain-workers.

Physiologists tell us that the way to provide for the welfare of the brain is to see that the rest of the body is in good order, that, in other words, the old proverb of "a sound mind in a sound body" is sound doctrine. And they are getting to tell us further that one way in which brain-work is hindered is by bad dietary habits, as, for instance, overloading the digestive organs by taking too much food. Of the vice of overeating (a vice which we Americans by no means monopolize) a considerable part, in this country at least, and I think in England and among well-to-do people on the Continent of Europe also, is the vice of fat-eating. We are a race of fat-eaters. If any one doubts this, I think the statistics to be shown in a succeeding article will convince him, unless he is ready to deny the practically unanimous testimony of such facts as I have been able to gather. It comes about very naturally and is really due to the fertility of our soil, the consequent abundance of food, and the toothsomeness of food-materials rich in fatty matters. The result of this is that the quantity of fat in the average Amercan's dietary is very large indeed, mainly because of the large amounts of meats, butter, and lard consumed, and is far in excess of the demands of his body, unless he is engaged in very severe muscular work or exposed to extreme cold, or both. For people with sedentary occupations, including the majority of brain-workers, this simply means charging the organism with the burden of getting rid of an excess of material. This excess, the physiologists and physicians assure us, is detrimental.

If the reader will take the trouble to look at Diagram III. of the previous article of this series, he will see that the flesh of fish contains less fat than ordinary meats. Some kinds, like salmon, mackerel, white-fish, and shad, are quite fat, but the flesh of cod, haddock, bass, blue-fish, perch, flounder, indeed the majority of our most common food fishes, has extremely little of fatty and oily matters.

Now it seems to me very reasonable to assume that brain-workers and other people who do not have a great deal of muscular exercise may very advantageously substitute fish in the place of a portion of the meat which they would otherwise consume. I am very well aware that such hygienic advice might come more appropriately from a physician than from a chemist, and am therefore glad to be able to quote from no less an authority than Sir Henry Thompson, who urges "the value of fish to the brain-worker" on the ground that it "contains, in smaller proportion than meat, those materials which, taken abundantly, demand much physical labor for their complete consumption, and which, without this, produce an unhealthy condition of body, more or less incompatible with the easy and active exercise of the functions of the brain."

Perhaps I ought to add that the studies of the constitution of the flesh of fish in this laboratory, referred to above, as well as similar investigations elsewhere, show that, so far as the nutritive qualities are concerned, the only considerable difference between fish and ordinary meats is in the proportions of oily and fatty matters and water. The flesh of the fish has water where meats have fat.

W. O. Atwater.

THE POTENTIAL ENERGY OF FOOD.

THE CHEMISTRY AND ECONOMY OF FOOD. III.

"Besides the . . . chemical elements, there is, in the physical world, one agent only, and this is called energy. It may appear, according to circumstances, as motion [heat], chemical affinity, cohesion, electricity, light, magnetism; and from any one of these forms it can be transformed into any of the others."—FR. MOHR.

"I have here a bundle of cotton, which I ignite; it burns and yields a definite amount of heat; precisely that amount of heat was abstracted from the sun, in order to form that bit of cotton; . . . every tree, plant, and flower grows and flourishes by the grace and bounty of the sun. But we cannot stop at vegetable life, for this is the source . . . of all animal life. In the animal body vegetable substances are brought again into contact with their beloved oxygen, and they burn within us as a fire burns in a grate. This is the source of all animal power, . . . all terrestrial power is drawn from the sun."—TYNDALL.

"All are but parts of one stupendous whole,
Whose body Nature is, and God the Soul;
That changed thro' all, and yet in all the same,
. . . . .
Lives thro' all life, extends thro' all extent,
Spreads undivided, operates unspent."—POPE.

WITHOUT doubt the two most fruitful ideas which our century has developed are those of evolution and the conservation of energy. The latter principle was, I believe, first clearly and definitely set forth in 1837,* just half a century ago, by Dr. Mohr, in the words quoted above.

During the years since then, the astronomers and geologists and physicists have been learning and explaining to us how the energy, whose primordial source in our solar system is the sun, warms and lights our planet; how it is stored in coal and petroleum and wood; and how it is transformed into the heat of the furnace, the light of the lamp, the mechanical power of steam, or into electricity and then into light or heat or mechanical power again. The same energy from the sun is stored in the protein and fats and carbohydrates of food, and the physiologists to-day are telling us how it is transmuted into the heat that warms our bodies and into strength for our work and thought. The potential energy of food may appear in still other forms; — in light, in certain animals, in the

"light of the fire-fly lamp,"

for instance, and even as electricity, in the animal body.

During the epidemic of strikes in the spring of 1886, a church was being built in this city (Middletown, Conn.). When the brick walls were partly laid, the hod-carriers struck for higher pay. The master mason, a man of resources, let them go and got a steam-engine in their place. The brick and the mortar which had been carried up the ladders by Hibernian muscle were lifted by engine and windlass. The work which had been done through the consumption of meat and potatoes in the one case, was accomplished by the combustion of coal in the other, but the underlying principle was the same in both. In each case there was conversion of one form of energy into another. The food which the hod-carriers ate, and the coal which was burned under the boiler, each contained a certain amount of potential energy. That of the food reappeared in the contractile power of muscle, that of the coal in the expansive power of steam.

Before the invention of matches, blacksmiths used to start their fires with iron heated by hammering. The heating of the iron was a case of the conversion of one form of energy into another. The muscular energy of the blacksmith's arm was transformed into the mechanical energy of the descending hammer; when the hammer struck, the energy was imparted to the iron, where it was transmuted into heat, and the iron became red-hot.

The energy came from the blacksmith's food.

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* In an article in the "Zeitschrift fur Physik und verwandte Wissenschaften," a journal published in Vienna. It is an interesting fact that these fifty years of unprecedentedly active and brilliant research have only confirmed, while explaining in detail, the principle thus laid down by a young and comparatively unknown German chemist. And it is a striking illustration of the lack of appreciation with which new ideas are often received, that Dr. Mohr's article, which contained this great generalization of modern science, was refused by "Poggendorff's Annalen," the leading German journal of physical science, before it was published in the Austrian journal above named. Dr. Mohr, it is true, did not prove the theory experimentally.

Just how all the potential energy of the food is disposed of in the body, experimental science has not yet told us. But it is certain that part of it is converted into heat and part into the mechanical energy exerted by the muscles. Some of it may be transformed into electricity. There is no doubt that intellectual activity, also, is somehow dependent upon the consumption of material which the brain has obtained from the food, but just what substances are consumed to produce brain and nerve force, and how much of each is required for a given quantity of intellectual labor, are questions which the chemist's balance and the respiration-apparatus do not answer.

ENERGY AND THE UNITY OF THE UNIVERSE.

THE introductory chapter of a German treatise on cattle-feeding explains the nebular hypothesis, a procedure which is perfectly rational when we consider that the profitable feeding of cattle is simply the economical management of matter and energy in living organisms, and that the nebular theory helps us, better than anything else, to understand how the forms of matter and of force which we have to do with have come to be what they are.

That the materials which compose this solid globe, the waters on its surface, the atmosphere around it, the things that live upon it, the planets with which it courses round the sun, the sun itself, and all the innumerable hosts of heavenly bodies that make up the material universe, are of common origin, is a doctrine familiar to us all. That in this material universe there are two things, and two things only, matter and energy, has come to be another of the accepted dicta of physical science. And current metaphysics goes a step farther and resolves matter itself into manifestations of energy.

It is this energy which pervades the universe. It comes to us in the light of the farthest star, which, though traveling with almost inconceivable rapidity, requires uncounted years for its journey hither. A reserve supply was accumulated in our sun, untold ages ago, and he has given and is constantly giving it to the earth as heat and light. In the geologic past it has accumulated in subterranean stores of coal, and it is now and all the while being used to build up every plant and animal that lives and grows upon the surface of our earth. The coal and wood we burn, our food, the reserve material of our bodies, are, like the sun, our reservoirs of latent energy.

This energy which, transmuted into the expansive power of steam, impels the ship, draws the railway train, turns the wheels of industry; which, in the telegraph, can "put a girdle round about the earth in forty minutes"; and which so conveniently transports men, their works, and their thoughts from one corner of the world to the other that the nations are all becoming one, is the same which, stored in the grass of the field or in the grain of wheat, gives the ox his strength, the race-horse his swiftness, and man his power of muscle and brain. Such are the grand conceptions which advancing knowledge brings us.

This energy is in the cyclone that devastates the land, as in the cooling zephyr of a summer's eve; it is in the awful rolling of the thunder and in the lightning's flash, as in the rustle of the leaves and the gentle cooing of the dove. It is in the tramping of armed hosts, the roar of artillery, and the carnage of battle, as in the soft caress and tender lullaby with which the mother sings and soothes her babe to sleep.

I often think that the greatest creation of human genius is the medieval cathedral. If this be so, and if the grandest music is that which floats through the cathedral aisles, if the loveliest transformations of the sunbeams are in the dim religious light that enters through its stained glass windows, if the holiest thoughts are those of its worshipers; the power that lifted the stones of the cathedral into their places, the light that reveals its grandeur and its beauty, the thought that planned its architecture and composed its music, the vibrations on which its music floats, the motions and the voices of those who bend

> "en murmurant sous le vent des cantiques
> Comme au souffle du nord un peuple de roseaux,"

and who, in responsive adoration, express the sentiments of its worship, are all, in one way or another, the products of that energy which once existed in space, rested for eons in the central orb of our system, and part of which, coming to us in those things which we designate as food, abides for a time in our own bodies and our own brains, to give us life and power and thought.

Says Professor Tyndall, in speaking of the law of conservation of energy:

> "Waves may change to ripples, and ripples to waves, magnitude may be substituted for number, and number for magnitude, asteroids may aggregate to suns, suns may resolve themselves into floræ and faunæ, and floræ and faunæ melt in air, the flux of power is eternally the same. It rolls in music through the ages, and all terrestrial energy, the manifestations of life, as well as the display of phenomena, are but the modulations of its rhythm."

Nor does he exaggerate, I think, in saying further:

> "Presented rightly to the mind, the discoveries and generalizations of modern science constitute a poem

more sublime than has ever yet been addressed to the intellect and imagination of man. The natural philosopher of to-day may dwell amid conceptions which beggar those of Milton. So great and grand are they, that in the contemplation of them a certain force of character is requisite to preserve us from bewilderment."

But, after all, this statement of a physical law is only the scientific form of the poetic thought expressed in the words of Pope quoted at the beginning of this chapter. Another poet, and one, it seems to me, whose soul was more exquisitely attuned to the harmonies of Nature than any other, has clothed this sentiment in still finer habiliment of words:

> "And I have felt
> A presence that disturbs me with the joy
> Of elevated thoughts: a sense sublime
> Of something far more deeply interfused,
> Whose dwelling is the light of setting suns,
> And the round ocean, and the living air,
> And the blue sky, and in the mind of man:
> A motion and a spirit, that impels
> All thinking things, all objects of all thought,
> And rolls through all things."
>
> WORDSWORTH.

What are the relations of this physical energy, whose "flux is eternally the same," to the Supreme Power that "impels all thinking things" and "rolls through all things," and "though changed through all" is "yet in all the same," it is the office of the metaphysician and the theologian rather than the chemist to discuss. But as physicists have found that all the forms of physical energy are really one, and chemists are aspiring to the proof that the different elements of which matter is composed are merely modifications of one primordial form, so I cannot forbear the conception, I might almost say belief, that one day the advance of knowledge will bring men to feel that the ideas thus framed in words by scientist and poet are one, not only with each other, but with the sentiment embodied in the words of an older and grander poet:

> "O Lord, how great are thy works! and thy thoughts are very deep. . . . But thou art the same, and thy years shall have no end. . . . Such knowledge is too wonderful for me; it is high, I cannot attain unto it. . . . If I ascend up into heaven, thou are there: if I make my bed in hell, behold, thou art there.
>
> "If I take the wings of the morning, and dwell in the uttermost parts of the sea;
>
> "Even there shall thy hand lead me, and thy right hand shall hold me."

Indeed, unless I wrongly apprehend the tendency of the speculation of our time, it is decidedly in this direction. In a late essay on "Religion, a Retrospect and Prospect,"* Mr. Herbert Spencer tells us that "amid the mysteries which become the more mysterious the more they are thought about, there will remain the one absolute certainty, that we are ever in presence of an Infinite and Eternal Energy, from which all things proceed." Such leaders of thought as Professors Lotze in Germany and Bowne in this country, and many other metaphysicians with them, teach that the things that we call matter are only forms of action of energy and that this energy is God immanent in the universe. And in his most exhilarating lectures on "The Idea of God," Mr. John Fiske says: "Instead of the force which persists let us speak of the Power which is always and everywhere manifested in phenomena. . . The everlasting source of phenomena is none other than the infinite Power that makes for righteousness"; and again: "The infinite and eternal Power that is manifested in every pulsation of the universe is none other than the living God."

In adopting these conceptions, then, which do away with the conflict between science and religion by making them one in origin and spirit; which teach us that even in the use of our daily bread we are linked to the Power whom we are taught to pray to give it to us; which help us to understand that without his knowledge, because without his action, not even the sparrow falls to the ground; and which help us to realize that the plainest and homeliest things that concern the welfare of our fellow-creatures are worthy of our most serious study and our profoundest thought; we are only following the current philosophy of the time.

That we do not think of these things every time we eat our bread and meat is very well, but such things are worth thinking of once in a while. If they were not, life would not be worth living. But I am wandering far afield and must come back to my subject.

AMOUNTS OF POTENTIAL ENERGY IN FOOD-MATERIALS.

MODERN physical science has taught how to measure the potential energy in combustible materials. The apparatus used is called a calorimeter, and the energy is measured by the amount of heat produced in burning the substances with oxygen, the equivalent of the heat in terms of mechanical energy being quite definitely known. The amounts of potential energy in different food-materials have been measured in this way.

Chemists and physiologists have thought for a long while that when the food is consumed in the body it must yield the same quantity of energy as when burned in the calorimeter. In both cases it is burned with oxygen, although the process in the body is far less simple than in the calorimeter. A number of years ago, Professor Frankland, of London, determined the heats of combustion of differ-

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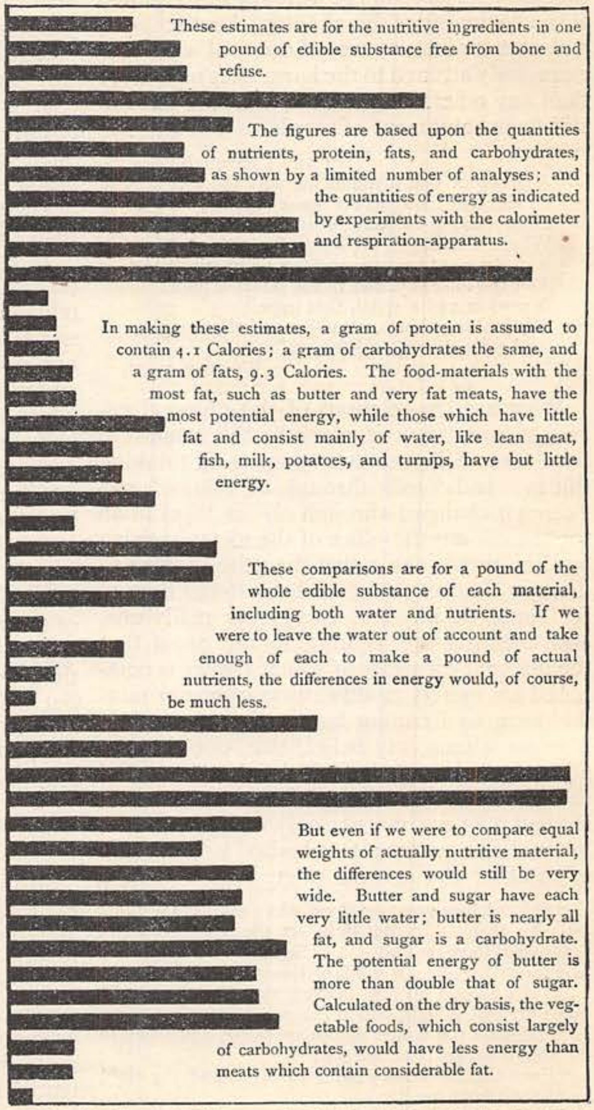
* The Nineteenth Century. Vol. XV.

DIAGRAM IV. POTENTIAL ENERGY OF FOOD.

CALORIES IN THE NUTRIENTS IN ONE POUND OF EACH FOOD-MATERIAL.

Beef, round, rather lean	807
Beef, neck	1108
Beef, sirloin, rather fat	1173
Beef, flank, very fat	2750
Beef, side, well fattened	1463
Mutton, leg	1142
Mutton, shoulder	1281
Mutton, loin (chops)	1755
Mutton, side, well fattened	1906
Smoked ham	1960
Pork, very fat	3452
Flounder	286
Cod	310
Haddock	331
Bluefish	404
Mackerel, rather lean	430
Mackerel, very fat	1026
Mackerel, average	696
Shad	750
Salmon	967
Salt cod	416
Salt mackerel	1364
Smoked herring	1343
Canned salmon	1036
Oysters	229
Hens' eggs	760
Cows' milk	308
Cows' milk, skimmed	176
Cheese, whole milk	2044
Cheese, skimmed milk	1166
Butter	3691
Oleomargarine	3679
Wheat flour	1655
Wheat bread	1278
Rye flour	1614
Beans	1519
Pease	1476
Oatmeal	1830
Corn (maize) meal	1616
Rice	1627
Sugar	1798
Potatoes	427
Sweet potatoes	416
Turnips	139



These estimates are for the nutritive ingredients in one pound of edible substance free from bone and refuse.

The figures are based upon the quantities of nutrients, protein, fats, and carbohydrates, as shown by a limited number of analyses; and the quantities of energy as indicated by experiments with the calorimeter and respiration-apparatus.

In making these estimates, a gram of protein is assumed to contain 4.1 Calories; a gram of carbohydrates the same, and a gram of fats, 9.3 Calories. The food-materials with the most fat, such as butter and very fat meats, have the most potential energy, while those which have little fat and consist mainly of water, like lean meat, fish, milk, potatoes, and turnips, have but little energy.

These comparisons are for a pound of the whole edible substance of each material, including both water and nutrients. If we were to leave the water out of account and take enough of each to make a pound of actual nutrients, the differences in energy would, of course, be much less.

But even if we were to compare equal weights of actually nutritive material, the differences would still be very wide. Butter and sugar have each very little water; butter is nearly all fat, and sugar is a carbohydrate. The potential energy of butter is more than double that of sugar. Calculated on the dry basis, the vegetable foods, which consist largely of carbohydrates, would have less energy than meats which contain considerable fat.

The potential energy represents simply the fuel-value of the food, and hence is only an incomplete measure of its whole nutritive value. Besides serving as fuel, our food has other uses, one of which is, if possible, still more important, namely, that of forming and repairing the tissues of the body, the parts of the machine. This latter work is done by the protein, which has comparatively little potential energy. Protein is the chief nutrient of lean meat and fish. These have, therefore, a high nutritive value, although their energy is comparatively small. (See Diagram III. of first article of this series.)

PROFESSOR EDWARD FRANKLAND.

ent food-materials, and his results have since been taken by many chemists and physiologists as the standard for their fuel-values when they are used for food, although with a certain amount of reserve, because of the lack of proof that the heat generated in the calorimeter is an accurate measure of the energy developed by the same materials in the body. The actual demonstration that this is the case, has been reserved for the refinements of later research.

Within a short time past, feeding-trials with animals in the respiration-apparatus have shown the proportions in which the several classes of nutritive ingredients of food do one another's work in serving as fuel in the body, and more extended experiments, with improved forms of the calorimeter, have given very accurate measurements of the amounts of potential energy in the same materials. The respiration experiments have been made with dogs, in the Physiological Institute in Munich, by Dr. Rubner, who has also made an extended series with the calorimeter. The largest number of the experiments with food-materials in the calorimeter, however, have been conducted by Professor Stohmann, of the University of Leipsic, and his assistants. The results of experiments with the respiration-apparatus and with the calorimeter agree with most remarkable closeness. In supplying the body with fuel, the protein, fats, and carbohydrates* replaced

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* The previous articles of this series have described the different kinds of nutrients of foods. Myosin (lean) of meat, white of egg, casein (curd) of milk, gluten of wheat, etc., are protein compounds. Fat of meat, butter, and oil of corn and wheat are fats. Starch and sugar are carbohydrates.

Since these German researches are very recent and have not yet been made accessible to English readers, I could hardly expect to be excused if I did not give at least an inkling of the details. Here is Dr. Rubner's summary of some of the main results of several long series of experiments, the descriptions of which occupy several hundred pages.

ISODYNAMIC VALUES
FOR ONE HUNDRED PARTS OF FAT.

Nutritive substances, water-free.	*As determined by direct experiments with animals.*	*As determined by calorimeter.*
Myosin	225	213
Lean meat	243	235
Starch	232	229
Cane sugar	234	235
Grape sugar	256	255

The quantities of the several substances, lean meat, myosin (the chief protein compound of lean meat), starch, etc., are those which were found to yield the same amounts of heat when burned in the calorimeter, or to render the same service as fuel when consumed in the body of the animal, as 100 grams of fat. This explanation of the meaning of the expression "isodynamic values for 100 parts of fat" needs a little qualification to make it perfectly correct, but it is as accurate as I can well make it without going into a discussion too abstruse for the pages of a magazine, and it is really accurate enough for our purpose. The figures mean, then, that the dogs in the respiration-apparatus obtained, on the average, as much heat to keep their bodies warm and energy for the work their muscles had to do, from 243 grams of lean meat (*i. e.*, meat enough to furnish 243 grams of nutritive material after the water had been driven out), as they obtained from 100 grams of fat, while 235 grams of the lean meat, burned to equivalent products in the calorimeter, would yield the same amount of heat as the 100 grams of fat. Considering the great difficulties in experimenting with live animals, these two isodynamic values, 243 by the respiration-apparatus and 235 by the calorimeter, agree very closely indeed. But with starch, the results by the two methods, 232 and 229, are still closer, while with ordinary table sugar and grape sugar they are as good as identical.

Taking our ordinary food-materials as they come, and leaving out slight differences due to the differences in digestibility, etc., Dr. Rubner has made the following general estimate of the amounts of energy in one gram of each of the three principal classes of nutrients. The Calorie, which is the unit commonly employed in these calculations, is the amount of heat which would raise the temperture of a kilogram of water one degree centigrade (or a pound of water 4 degrees Fahrenheit). Instead of this unit of heat we may use a unit of mechanical energy, for instance the foot-ton, which is the force that would lift one ton one foot. One Calorie nearly corresponds to 1.53 foot-tons.

POTENTIAL ENERGY IN NUTRIENTS OF FOOD.

	Calories.	*Foot-tons.*
In one gram of protein	4.1	6.3
In one gram of fats	9.3	14.2
In one gram of carbohydrates	4.1	6.3

These figures mean that when a gram (one twenty-eighth of an ounce) of fat, be it the fat of the food or each other in almost exact proportion to their heats of combustion. That the living body should thus be proved to use its food with such perfect chemical economy is certainly interesting and important. It is one more fact to add to the long lists that are bringing the functions of life more and more within the domain of ordinary physical and chemical law.

The diagram of "Potential Energy of Food" herewith indicates the amounts of potential energy in different food-materials. The estimates are for one pound of each material; that is to say, for one pound of edible substance, freed from refuse, as for instance, meat without bone or the shell-contents of eggs. It is of course to be understood that the materials vary in composition and that these figures represent averages merely. In fact, both the analyses of the food-materials and the researches upon the potential energy of the nutrients are as yet far too limited in extent to be entirely satisfactory. The diagram is like a map of a new country, based upon the first explorations; in the main correct, but in need of more complete surveys to make it accurate in all its details.

By these calculations, a pound of wheat flour contains as much energy, to be converted into the heat which a laboring man needs to keep his body warm, and muscular strength to do his work, as two pounds of lean beef free from bone, while a pound of very fat pork is equal to over four pounds, and a pound of butter to nearly five pounds of the very lean beef. That is, the quantities of latent energy in lean beef, flour, fat pork, and butter, are to each other as one, two, four, and five.

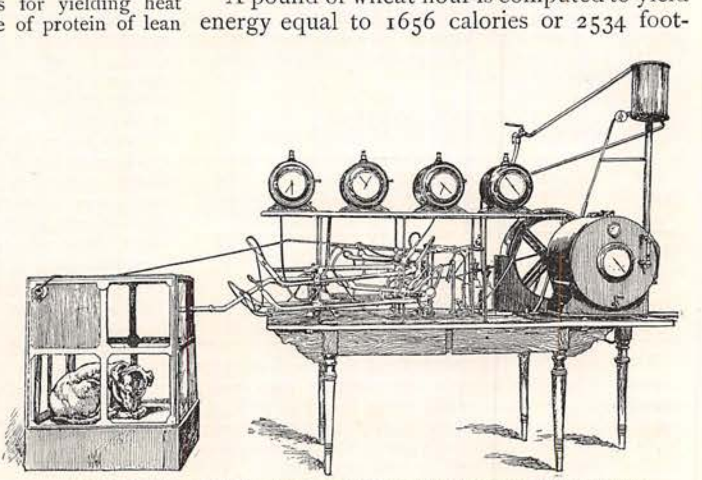
That these food-materials should differ so greatly in fuel-value may, at first sight, seem a little strange. But when we compare the composition of the very fat and the very lean meat, as shown in Diagram III. of the first article of this series (May CENTURY), the reason becomes clear. The very lean meat consists mostly of water, which has no potential energy, while the very fat meat has extremely little water and is composed mainly of fat, which has more potential energy than any other nutrient. The difference between the very fat meat and the wheat flour is not due so much to difference in their proportions of water, for they have nearly the same, but rather to the fact that flour consists largely of starch, which has relatively little potential energy. Butter and oleomargarine lead all the other materials in their quantities of energy. The fat of butter is slightly inferior in this respect, weight for weight, to the fat of meat, the proportions as found by experiment being as 92 to 94, nearly.

I fear I have not yet made quite clear just what these statements and the figures in the diagram actually mean.

A pound of wheat flour is computed to yield energy equal to 1656 calories or 2534 foot-

body-fat, is consumed in the body, it will, if its potential energy be all transformed into heat, yield enough to warm a kilogram of water nine and three-tenths degrees of the centigrade thermometer, or, if it be transformed into mechanical energy such as the steam-engine or the muscles use to do their work, it will furnish as much as would raise one ton fourteen and two-tenths feet or fourteen and two-tenths tons one foot. A gram of protein or carbohydrates would yield a little less than half as much energy as a gram of fat. In other words, when we compare the nutrients in respect to their fuel-values, their capacities for yielding heat and mechanical power, an ounce of protein of lean meat or albumen of egg is just about equivalent to an ounce of sugar or starch; and a little over two ounces of either would be required to equal an ounce of the fat of meat or butter or body-fat. The potential energy in the ounce of protein or carbohydrates would, if transformed into heat, suffice to raise the temperature of one hundred and thirteen pounds of water one degree Fahrenheit, while an ounce of fat, if completely burned in the body or in the calorimeter, would yield as much heat as would warm over twice that weight of water one degree.

The calculations of Diagram IV. are based upon the figures just given for the potential energy of each nutrient. The figures used for the quantities of each nutrient in each food-material of Diagram IV. are the same as those on which Diagram III. of the first article of this series is based.



SMALL RESPIRATION-APPARATUS IN THE MUNICH PHYSIOLOGICAL INSTITUTE.

This apparatus, which is, in principle, identical with the large apparatus described in the previous article of this series, was devised by Prof. Voit, and intended for experiments with dogs, geese, and other small animals. Its object is to provide for analysis of the air before and after it has been breathed by the animal, and thus show what products of respiration the animal has imparted to it. The box in which the animal is kept is made of glass. Through this box a constant current of air is drawn and measured by the large meter on the table. A small portion of this, however, is drawn through two of the small meters by which it is measured, and through apparatus on the table by which it is analyzed. Air taken from outside the box is at the same time drawn through the other two small meters and apparatus on the table, and thus measured and analyzed in like manner.

tons. But this of course does not mean that if the pound of flour were made into bread, it would enable our blacksmith, if he should eat it, to lift 2534 tons of iron to a height of one foot, or the hod-carrier to carry a ton of bricks to the height of 2534 feet. He could do only a small fraction of this work with his loaf of bread.

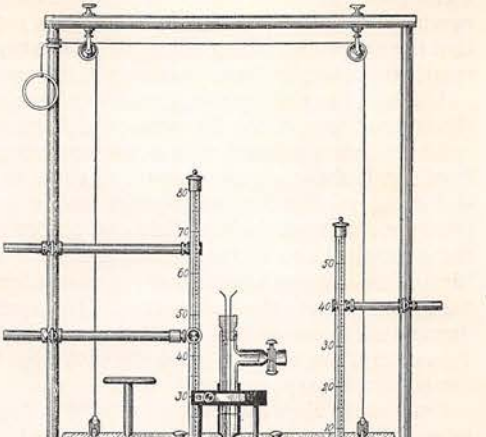
Only a very small proportion of the whole energy of the food is made available for external muscular work, such as the hod-carrier's lifting, the blacksmith's hammering, or other manual labor; the most of it is transformed into heat. A considerable quantity is used for the interior work of the body, breathing, keeping the blood in circulation, digestion, etc., but a large part of this is transformed into heat before it leaves the body. Thus the mechanical energy imparted to the blood by the muscles of the heart is changed to heat by the friction of the blood against the vessels through which it circulates. Indeed, there is an old theory that it is this friction that gives the body its heat.

The heat generated in the body, by the combustion of food and otherwise, is continually given off by radiation. With plenty of clothing we can retain enough to keep ourselves warm even in a cold day. Too much clothing may so interfere with radiation as to make us uncomfortably warm. The amount of heat produced in the body is so large that it has been calculated that, if there were no way for it to escape, there would be enough in an average well-fed man to heat his body to the temperature of boiling water in thirty-six hours.

We have a very familiar illustration of the production of heat along with muscular energy in the heating of our bodies when we exercise our muscles. We cannot transform the energy of our food into muscular force without transmuting part of it into heat at the same time. In the body, indeed, as with the steam-engine, but a small part of the energy of the fuel is transformed into mechanical power for work. But the body is more economical in this respect than the best steam-engine; that is to say, it gets more power for work from the same amount of energy in its fuel. It has been estimated that while the most efficient steam-engines cannot get more than one-eighth of the energy of their fuel in the form of mechanical power, the body can get one-fifth. Some calculations, indeed, make a far more favorable showing for the animal as compared with the machine in respect to economy in the use of fuel for work. Professor von Gohren, as the result of elaborate computations, reckons that

A horse may transform 32 per cent.
An ox " " 43 " "
A man " " 53 " "

of the whole potential energy of his food into energy for mechanical work. More research is needed, however, before entirely satisfactory calculations of this sort can be made.



CALORIMETER.

The calorimeter here shown is a late form devised by Prof. Stohmann. Within is a small cylinder, S, in which the substance to be tested is burned, being mixed for this purpose with materials furnishing oxygen. This cylinder is surrounded by a cylindrical cover, and is contained in a larger cylinder, W, holding water. The heat from the burning substance is communicated to the water, and is measured by the rise in temperature as shown by the thermometer. Outside of the cylinder holding the water are two concentric cylinders, A, A, holding air which acts as a non-conductor of the heat. The air-cylinders are surrounded by a larger cylinder containing water, which, in its turn, has a covering of felt, the object being to guard against the influence of changes of temperature of the outer air. The further devices for protecting the interior apparatus from gain or loss of heat, igniting the inner mixture in the inner cylinder and measuring the heat produced by the combustion, need not be described here. The whole apparatus is about eighteen inches wide and a little over three feet high.

But to come back to the energy in our hod-carrier's pound of flour. If four-fifths are transformed into heat in his body and only one-fifth into muscular force for work, this would give him 500 foot-tons of muscular energy. But when he climbs the ladder with his hod of bricks he must carry his body and the hod up and down again; the power his muscles use to lift their load is not applied directly but through a complex system of levers in his limbs, and much of the power is used in other ways; so that the amount of lifting of bricks bears a very small proportion to the total energy of the food.

Just as I am writing this, the last volume of the transactions of the Bavarian Academy of Sciences comes to hand, with a communication from Dr. Rubner, giving account of some new and extremely interesting experiments in this direction. I hope the fact that one object of these articles is to report the latest news from the field of abstract research will excuse at least a brief reference to the main results. The experiments were in continuation of those mentioned above, and, like them, were made with dogs in the respiration-apparatus.

One principle which they bring into clear relief is the remarkable economy with which the animal organism uses its material when the supply is limited, and the positive wastefulness it practices when the food-supply exceeds the demand.

The dogs had very little room to move about inside the apparatus and of course made very little muscular exertion. Hence they needed but little protein to make up for the wear of muscle, and, practically, the main demand of their bodies was for fuel to yield heat to warm their bodies and strength for the very little work their muscles had to do. When they fasted, they consumed the fat and protein from the store in their bodies. How rigidly economical they were in this draft upon their previously accumulated capital was shown in the way that the consumption of fuel was affected by the temperature of the room. The interior temperature of the body remained very nearly the same, at "blood-heat," all the while, as indeed it must, or the dogs would have died. In cold days more heat was radiated from the body than in warm, more was needed to supply its place, and more material was consumed. When the room was warmer the body burned less fuel. And the quantities consumed marked the changes of temperature with a delicacy almost comparable with that of the thermometer.

When the dogs had just food enough to supply their needs they used it with similar economy. In other words, when the income was equal to the necessary expenditure it was used as sparingly as the sums taken from the capital had been. When the food-supply was made larger, part of the extra material was stored in the body as fat and protein, but at the same time the daily consumption increased. That is to say, when their income was more liberal, they laid part of it by, but at the same time allowed their current expenses to increase. It has been found by numerous experiments that when the nutrients are fed in large excess the body may continue for a time to store away part of the extra material, but after it has accumulated a certain amount it refuses to take on more, and the daily consumption equals the supply even when this involves great waste. With the large income, the body continues for a time to add to its capital, but finally it comes to spend as much as it gets, and in so doing practically throws away what it cannot profitably use.

Dr. Rubner's dogs showed, in still another way, their economy of fuel when the supply was limited, and wastefulness when they had more than they needed. The same animal that adjusted its consumption of fuel so accurately to the temperature of the air as long as the amount did not exceed its need, used it with no apparent regard to the temperature, whether warm or cold, as soon as the supply of food exceeded the necessary demand.*

This all seems very simple and natural. So the laws of nature always do when we have discovered and begin to understand them.

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* Physiologists have observed that the consumption of fuel in the body sometimes varies with the temperature and sometimes does not, and have been at a loss to explain the apparent discrepancies in their experimental results. These experiments help toward an explanation. But the interesting point is, not simply that the facts are learned, but that they are learned by studying the subject from the standpoint of the potential energy of the food. Previously, the accounts have, so to speak, been drawn up in terms of protein, carbohydrates, and fats, and the balances have been difficult to calculate and still more difficult to explain. But in the experiments of which I have just been speaking, all the figures were reduced to terms of potential energy of the food and body-substance consumed or stored. The results were calculated in Calories, and the balancing of the accounts was thus made simple, and the explanation plain.

Of course I do not mean to say that we have thus suddenly come upon a complete explanation of the whole subject. This is simply an improvement of methods based on clearer understanding of principles and leading to clearer and more accurate results. It is, in short, the old story of clearing up an old mystery by use of a new and rational idea. As such, as well as for stronger reasons, it is of interest.

It is so easy to magnify the importance of any new discovery, and so hard to avoid going too far in drawing inferences from it, that I am inclined to put in another word of caution here. For instance, from the experiments above described one would infer that the food-ingredients yield strength for muscular labor in exact proportion to their heats of combustion. But the dogs in the respiration-apparatus performed no muscular work except that inside their bodies for respiration, keeping the blood in circulation, etc., and though we naturally assume that if they had used their muscles for exterior work, such as running or working a treadmill, the muscular energy yielded by the food would have been likewise equal to its potential energy, and though the other known facts make this assumption entirely probable, the experiments do not absolutely prove it. The production of muscular strength is a problem which is still but partly solved. Still I think it is reasonably safe to say that, in general, the foods that have the most potential energy are the ones that yield, not only the most heat to keep the body warm, but also the most strength for muscular work.

THERE are numerous homely, practical ways in which these principles may be applied. I well remember how the sensible and thrifty New England people among whom my boyhood was spent used to talk about "hearty victuals," and how prevalent were the doctrines that "a hard-working man wants real hearty food," and that "children ought to have hearty food, but not too hearty.".

With these eminently orthodox tenets the science of nutrition in its newest developments is in fullest accord. But there always used to be an unsatisfactory vagueness about them. I never could make out exactly what were "hearty" foods, and in just what their heartiness consisted. It has since occurred to me that these words express one of the ideas which the unerring sense and instinct of man have wrought out of his long experience, but have waited for science to put into clear and definite form. The synonym with which our science defines this idea is energy. Hearty foods are those in which there is an abundance of potential energy.

The lumbermen in the Maine forests work intensely in the cold and snows of winter and in the icy water in the spring. To endure the severe labor and cold, they must have food to yield a great deal of heat and strength. Beans and fat pork are staple articles of diet with them, and are used in very large quantities. The beans supply protein to make up for the wear and tear of muscle, and they, and more especially the pork, are very rich in energy to be used for warmth and work.

I cannot vouch for the following, which has just struck my eye in a daily paper, but, if it is true, the workmen were sound in their physiology:

> "A lot of woodchoppers who worked for Mr. S—— in H—— stopped work the other day, and sent a spokesman to their employer, who said that the men were satisfied with their wages and most other things, but didn't like 'your fresh meat; that's too fancy, and hain't got strength into it.' Mr. S—— gave them salt pork three times a day, and peace at once resumed its sway."

The use of oily and fatty foods in arctic regions is explained by the great potential energy of fat, a pound of which is equal to over two pounds of protein or starch. I have been greatly surprised to see, on looking into the matter, how commonly and largely the fatter kinds of meat are used by men engaged in very hard labor. Men in training for athletic contests, as oarsmen and foot-ball teams, eat large quantities of meat. I have often queried why so much fat beef is used, and especially why mutton is often recommended in preference to beef for training diet. Both the beef and the mutton are rich in protein, which makes muscle. Mutton has the advantage of containing more fat along with the protein, and hence more potential energy. Perhaps this is another case in which experience has led to a practice, the real grounds for which have later been explained by scientific research.

The Germans have, in their vernacular, hit closer to the principle here explained than we. Their scientific expression for energy is *Kraft*. In their folk-tongue the word for nourishing, strength-giving, is *kräftig*. When, as a newcomer, I first looked for a boarding-place in a German city, I was amused at the recurring assurances from would-be hosts and hostesses, that their fare was *kräftig*. With the abundance that crowns even the humble board at home, I had not learned how much that word and the idea it carried could mean in less favored lands.

W. O. Atwater.

CROOKED JOHN.

THE Von Gravens had once been a great family; but reckless living had ruined them. They were large, handsome men, with blue eyes and a distinguished bearing. No end of stories were told in the valley of their bright sayings and their foolhardy deeds. Some of their observations, I regret to say, were not for ears polite. Colonel Von Graven, who, with his son Harold, was now the only bearer of the name, was understood to have been a lady-killer in his day. When his dignity thawed out over a glass of toddy, he had been known to make allusion to his adventures in that line; and when the judge gave him a dig in the ribs and called him a gay old boy, he did not resent it.

Harold, the colonel's son, was a regular dare-devil. They called him "the girls' Harold," because he had such a taking way with women. Nobody could hold a candle to him on the dancing-floor; and the colonel rubbed his hands and chuckled when he saw him take to love-making as a duck does to water. Ah, yes, he made havoc in the hearts of the girls in those days — mere lad as he was.

Then it was that one fine day in the spring there was a log-jam in the river. The water rose several feet an hour, and there was a roar in the air as of a hundred chariots. Two men had gone to the bottom in trying to break the jam, and it seemed sure death for the third and the fourth. The cataract thundered below, and the yellow foam flew high over the tree-tops. The

THE DIGESTIBILITY OF FOOD.

THE CHEMISTRY OF FOODS AND NUTRITION. IV.

"We live upon, not what we eat, but what we digest."—MEINERT.

"Now good digestion wait on appetite, and health on both."—MACBETH.

We have been talking of the different kinds of nutritive substances of food and the ways in which they nourish our bodies, but have thus far omitted one of the very important factors of their nutritive value, their digestibility. The value of food for nutriment depends not only upon how much of nutrients, protein and fats and the like, it contains, but also upon how much of these the body can digest and use for its support.

The question of the digestibility of foods is very complex, and I have noticed that the men who know most about the subject are generally the least ready to make definite and sweeping statements concerning it. One of the most celebrated physiologists of the time, an investigator who has, I suppose, devoted as much experimental study to this particular subject as any man now living, declares that, aside from the chemistry of the process, and the quantities of nutrients that may be digested from different foods, he is unable to affirm much of anything about it. The contrast between this and the positiveness with which many people discourse about the digestibility of this or that kind of food, is very marked and has its moral.

One source of confusion is the fact that, what people commonly call the digestibility of food includes several very different things; some of which, as the ease with which a given food-material is digested, the time required for the process, the influence of different substances and conditions upon digestion, and the effects upon comfort and health, are so dependent upon individual peculiarities of different people, and so difficult of measurement, as to make the laying down of hard and fast rules impossible. Why it is, for instance, that some persons are made seriously ill by so wholesome a material as milk, and others find that certain kinds of meat, of vegetables, or of sweetmeats, "do not agree with them," neither chemists nor physiologists can exactly tell. Late investigations, however, suggest the possibility that the ferments in the digestive canal may, with some people, cause particular compounds to be changed into injurious and even poisonous forms, so that it may sometimes be literally true that "one man's meat is another man's poison."*

But digestion proper, by which we understand the changes which the food undergoes in the digestive canal in order to fit the digestible portion to be taken into the blood and lymph and do its work as nutriment, is essentially a chemical process. About this a great deal has been learned within a comparatively few years, so that here again we have many important facts that have not yet got into current literature. In explaining about them perhaps it will not be out of the way to repeat some of the things we learned in studying chemistry and physiology. We will start with the facts that the first thing the body does with the food is to digest it; that the digestion is done in that long irregular shaped piece of apparatus — laboratory is perhaps a better word — which consists of mouth, œsophagus, stomach, and intestines, and which is called the alimentary canal; that it is next converted into blood; that to get into the blood it must pass through the sides, the walls, of this canal; and that it is only after the food has been digested

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* We are hearing a great deal of late about poisons in food containing protein compounds, such as the casein of milk and the myosin of lean meat and fish. The protein compounds are prone to decay, that is, to be decomposed by the action of the ferments called bacteria or microbes. In certain forms of decomposition, substances of a more or less poisonous nature, called ptomaïnes, are formed from protein. It appears to be in this way that poisonous compounds are formed in cheese, meats, etc. While the true digestive ferments, such as the ptyalin of saliva and pepsin of gastric juice, are very different from the ferments just spoken of, yet microbes exist in the digestive apparatus of even the healthiest people, and within a short time past it has been found that poisonous compounds, formed probably by the action of microbes, often occur within our bodies. The natural inference—it is not positively proved, I think —is that there may be cases in which the protein of certain kinds of food is thus transformed into injurious substances while passing through the alimentary canal. Perhaps this is the reason why certain persons cannot endure milk without pain or nausea, and it is not impossible that many of the cases in which one kind of food or another causes sickness, may, in the light of future research, be attributed to such fermentations within the body.

and has worked its way into the blood and lymph that it can be distributed through the body and made into tissue, stored for future use, or burned for fuel.

I doubt if most of us realize what an amount of chemical activity the stomach and intestines must put forth, what a wonderful laboratory that must be which transforms our food into the constituents of blood. The average man swallows, say, six pounds of food and drink, meat, potatoes, bread, coffee, milk, water, and what not, per day. Every twenty-four hours, then, all the solid substance, all the protein, fats, carbohydrates, and mineral matters of this quantity of food, except the small portion that passes through the alimentary canal undigested, must be either dissolved or divided into such minute particles as to be able to get through the microscopic passages that permeate the walls of the alimentary canal, and thus find their way to the blood.

THE CHEMISTRY OF DIGESTION.

PROFESSOR MALY very aptly compares food to ore, and the nutriment we digest from it to the metal extracted from the ore. In the chemical laboratory we sometimes separate a metal from the earthy matters with which it is mingled by pulverizing the ore, putting it in a flask, pouring acids upon it, and stirring the whole together. The acids dissolve the metal, leaving a residue of earthy matters undissolved. To separate the dissolved materials from the residue, we pour the whole upon a paper filter. The solution runs through the interstices of the paper into a dish below, leaving the undissolved residue in the filter.

Something analogous to this takes place in the digestion of food. Instead of the metal and earthy matters of the ore, we have the digestible and the undigestible constituents of meat, or bread, or other food. The grinding is done, not by pestle and mortar, but by the teeth; the digestive juices are the solvents; in the place of the flask the dissolving is done in the digestive apparatus, the stomach and intestine. Finally, the digested material has to pass, not through a filter, but through the porous walls of these last organs. The changes which the digestive juices cause are manifold. The saliva with its ptyalin transforms the insoluble starch of bread and potatoes into soluble sugar. The pepsin of the gastric juice supplied by the stomach and the tyrpsin of the pancreatic juice which comes from the pancreas, convert the myosin of meat, the casein of milk, the albumen of egg, the gluten of wheat, and other protein compounds of the food into soluble peptones. The gall acts upon the oily and fatty matters, besides doing other duties. As the food in process of digestion is gradually propelled along the intestine, still another fluid, the intestinal juice, acts upon it. In these and other ways more or less perfectly understood, the digested matters are either dissolved or otherwise altered so that they can filter into the blood (though the process is different from ordinary filtration), and be thus conveyed to all parts of the body.

IN the first of the quotations at the beginning of this article, a German student of food-economy gives terse expression to the fact that we are nourished by that part of the food which is actually digested. To judge accurately of the nutritive value of our food, then, we must know how much of each nutrient will be digested. This is a matter that can be determined more or less accurately by experiment. But a great deal of labor is needed to make the experiments accurate, the line of research is new, the methods are not yet perfectly matured, and the results thus far obtained, though interesting and valuable when taken together, are still very far from complete. The side questions, such as differences in the digestive apparatus of different persons, the effects of exercise and rest, or the mode of preparation of the food, and of the flavoring materials and beverages taken with it, tend to complicate the problem and make satisfactory results still harder to obtain. Yet even here experimental research has something to tell us.

The ways in which the experiments to test the digestibility of foods are made are very ingenious and interesting. Physiologists use the salivary glands or stomach or intestine of a living animal much as chemists do their bottles and retorts and test tubes. One easily gets into the way of regarding an animal as simply an organism manifesting certain reactions under given conditions, and in not a few European laboratories a janitor is readily induced by the price of a few months' supply of beer, or a student by his scientific ardor, to take this same altruistic view of his own physical organism. In the German laboratories, particularly, one finds not only the needed apparatus, but, what is no less important, trained assistants and servants, so that he is relieved of much of the time-consuming and disagreeable detail of experimenting, which is so much of an obstacle with us.

THE QUANTITIES OF DIGESTIBLE SUBSTANCES IN FOOD.

THE first of our questions may be put in this way: What proportion of each of the nutrients in different food-materials is actually digestible? In a piece of meat, for instance, what percentages of the total protein and fats will be digested by a healthy person, and what proportion of each will escape digestion?

The proportions of food-constituents digested by domestic animals has been a matter of active investigation in the European agricultural experiment stations during the past twenty years. Briefly expressed, the method consists in weighing and analyzing both the food consumed and the intestinal excretion. Since the latter represents the amount of food undigested, if we subtract it from the whole amount taken into the body the difference will be the amount digested.

Such experiments upon human subjects, however, are rendered much more difficult by the fact that in order that the digestibility of each particular food-material may be determined with certainty, we must avoid mixing it with other materials. Hence the diet during the experiments must be so plain and simple as to make it extremely unpalatable. An ox will live contentedly on a diet of hay for an indefinite time, but for an ordinary man to subsist a week on meat or potatoes or eggs is a very different matter. No matter how palatable such a simple food may be, at first, to a man used to the ordinary diet of a well-to-do community, it will almost certainly become repugnant to him after a few days. In consequence, the digestive functions are disturbed, and the accuracy of the trial is impaired, a fact, by the way, which strikingly illustrates the importance of varied diet in civilized life.

For instance, in one of a series of experiments conducted in the physiological laboratory at Munich, by Dr. Rubner, the subject, a strong, healthy Bavarian laborer, lived for three days upon bread and water, a diet, the monotony of which was much more endurable than one of meat or fish or almost any other single food-material would have been. He was able to eat 1185 grams (about 2 lbs. and 10 oz.) of bread per day. This contained 670 grams of carbohydrates, mainly starch, of which only about 5 grams, or a little less than one per cent., escaped digestion. In this case, therefore, about 99 per cent. of the carbohydrates of the bread was digested. The bread contained 81 grams of protein, of which 13 per cent. was undigested and 87 per cent., or ⅞ of the whole protein, digested. The quantity of fatty matters in the bread was too small to permit an accurate test of their digestibility. In another series, conducted by myself in the same laboratory, the digestibility of meat in the form of beefsteak, and of fish, haddock, was tested. The subject, a medical student, consumed less than two pounds of meat per day, and though it was cooked with butter, pepper, salt, and onions, so as to make it to his taste, "extraordinarily well flavored," it was very difficult for him to swallow it the second day, and required still greater effort the third. The digestion, however, seemed to be normal, and all but about one per cent. of the protein was digested.* Other trials with meat have brought similar results, and it is reasonably safe to say that when a healthy person, with sound digestive organs, eats ordinary meat or fish in proper quantity, all or nearly all of the protein is digested. Some of the fats of meat, however, seem to fail of digestion.

The number of accurate experiments of this kind is still very small. Some sixty or thereabouts have been reported. Nearly all have been made within ten years past, and the majority in one laboratory, that of the University of Munich. Most of the subjects have been men with healthy digestive organs, two or three laboratory servants, a soldier, several medical students, and a few others. Several have been made, however, with children of a few families. All but a very small number have been conducted in Germany.

Digestibility of Nutrients of Food-materials.

In the food-materials below.	Of the total amounts of protein, fats, and carbohydrates, the following percentages were digested:		
	Protein.	*Fats.*	*Carbohydrates.*
Meats and fish.........	Practically all	79 to 92	
Eggs..................	"	96	
Milk..................	88 to 100	93 to 98	?
Butter................	....	98	
Oleomargarine.........	....	96	
Wheat bread...........	81 to 100	?	99
Corn (maize) meal.....	89	?	97
Rice..................	84	?	99
Pease.................	86	?	96
Potatoes..............	74	?	92
Beets.................	72	?	82

Some of the main results are summarized in the tabular statement herewith, and set forth graphically in the diagram on page 736. As there appears to be good ground for believing that in some cases in which the smaller percentages were digested the conditions were not entirely normal, I have omitted them in making the calculations for the table and diagram. Thus, in the diagram it is assumed that all of the protein of milk is digestible, though in some experiments part was left undigested. The methods of experimenting do not permit absolute accuracy, and the results with different persons and with different specimens of the same food-material vary somewhat. The greatest errors in the estimates in the table and chart are probably in the fats, which may be more completely digested than the figures imply.

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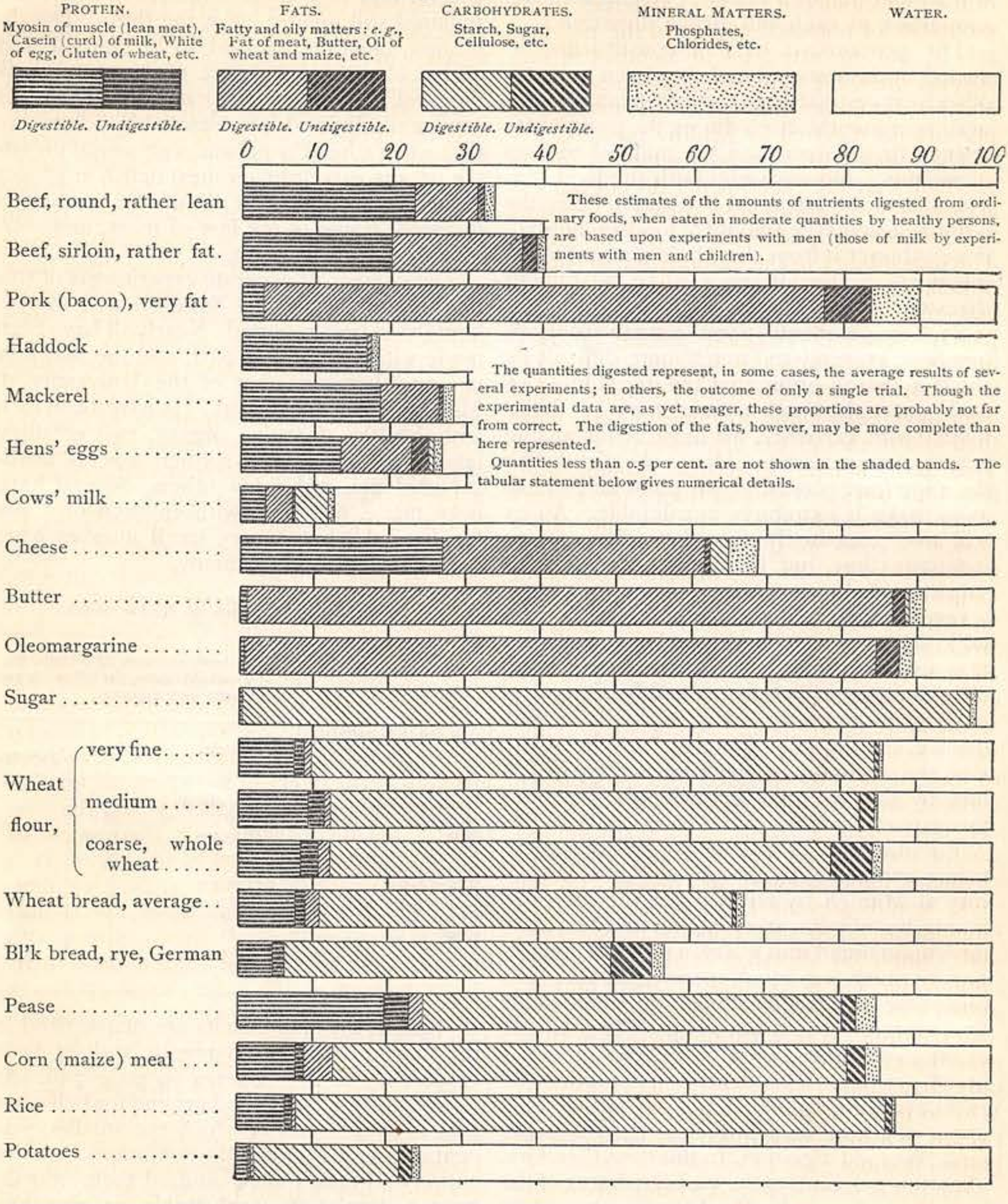
* Zeitschrift für Biologie, XV. and XXIV.

PROPORTIONS OF NUTRIENTS DIGESTED AND NOT DIGESTED FROM FOOD-MATERIALS BY HEALTHY MEN.

Percentages indicated by Shaded Bands.



These estimates of the amounts of nutrients digested from ordinary foods, when eaten in moderate quantities by healthy persons, are based upon experiments with men (those of milk by experiments with men and children).

The quantities digested represent, in some cases, the average results of several experiments; in others, the outcome of only a single trial. Though the experimental data are, as yet, meager, these proportions are probably not far from correct. The digestion of the fats, however, may be more complete than here represented.

Quantities less than 0.5 per cent. are not shown in the shaded bands. The tabular statement below gives numerical details.

	PROTEIN.		FATS.		CARBOHYDRATES.		MINERAL MATTERS.	WATER.
	Total.	*Undigestible.*	*Total.*	*Undigestible.*	*Total.*	*Undigestible.*		
	per ct.	per ct.	per ct.	per ct.	per ct.	per ct.	per ct.	per ct.
Beef, round	23.0	0.0	9.0	0.9	0.0	0.0	1.3	66.7
Beef, sirloin	20.0	0.0	19.0	1.9	0.0	0.0	1.0	60.0
Pork, very fat	3.0	0.0	80.5	6.0	....	....	6.5	10.0
Haddock	17.1	0.0	0.3	....	0.0	0.0	1.2	81.4
Mackerel	18.8	0.0	8.2	0.8	0.0	0.0	1.4	71.6
Hens' eggs	13.4	0.0	11.8	2.4	0.7	0.0	1.0	73.1
Cows' milk	3.4	0.0	3.7	0.1	4.8	0.0	0.7	87.4
Cheese, whole milk	27.1	0.0	35.5	0.9	2.3	0.0	3.9	31.2
Butter	1.0	....	87.5	1.7	0.5	....	2.0	9.0
Oleomargarine	0.4	....	87.2	3.3	0.0	....	2.1	10.3
Sugar	0.3	....	....	....	96.7	0.0	0.8	2.2
Wheat flour, very fine	8.9	1.3	1.0	....	75.2	0.8	0.3	14.6
Wheat flour, medium	11.6	2.1	0.8	....	72.2	1.8	0.4	15.0
Wheat flour, coarse, whole wheat	10.9	2.7	1.8	....	71.7	5.3	1.2	14.4
Wheat bread, average	8.9	1.2	1.9	....	55.5	0.6	1.0	32.7
Black bread	6.1	1.6	....	....	48.6	5.3	1.5	43.8
Pease	22.9	3.2	1.8	....	57.8	2.1	2.5	15.0
Corn (maize) meal	9.1	1.2	3.8	....	71.0	2.3	1.6	14.5
Rice	7.4	1.2	0.4	....	79.4	0.7	0.4	12.4
Potatoes	2.0	0.5	0.2	....	21.3	1.6	1.0	75.5
Turnips	1.0	0.3	0.2	....	6.9	1.3	0.7	91.2

Though the experimental data are as yet very meager, so much so that no account is taken of the digestibility of the food-materials in the estimates for potential energy in the previous article, nor for estimates of dietaries in succeeding ones, the figures here given are probably not far out of the way as indicating the proportions digested by healthy persons.

The amounts of fat in the vegetable foods are so small that the experiments do not tell exactly what proportions are digested. The meats and fish contain practically no carbohydrates. The digestibility of the carbohydrates (sugar) of milk was not determined, those of the vegetable foods, except the beets, were almost completely digested. That the protein of cows' milk should be so much less completely digested than that of meat seems a little strange. Children have been found to digest a little more than adults, though the difference is not large. Thus Dr. Camerer, a German experimenter, found his boys and girls, of from 2 to 12 years of age, digested from 91 to 97 per cent. of the protein of cows' milk, while grown men in experiments by Dr. Rubner digested from 88 to 94 per cent. But in experiments in which milk and cheese were eaten together by a man, the laboratory servant of Dr. Rubner's experiments, all or nearly all of the protein of both was digested. Dr. Rubner suggests an explanation of the more nearly complete digestion of the milk when taken with cheese than when taken by itself alone. When taken into the stomach without anything else, cows' milk is apt to coagulate in large lumps which resist the action of the digestive juices. The particles of cheese, if finely chewed and mixed with the milk, would prevent the formation of such large lumps, and it would thus be more readily and completely digested. This seems very reasonable. The percentage of fats of milk digested was practically the same with adults as with children. It is worth noting that in these experiments both children and adults digested only about half of the mineral salts of the milk. Why so much of the fats of the meat, from a twelfth to a fifth, should have failed to be digested, it is not easy to say.

Much has been said and written about the relative digestibility of butter and oleomargarine. The only actual comparative tests on record are a series made with a man and boy by Professor Mayer, in Holland. In these from 97.7 to 98.4 per cent. of the fat of the butter and from 96.1 to 96.3 per cent. of the fat of the oleomargarine were digested. The average difference was 1.6 per cent. in favor of the butter. Certain possible sources of error in such experiments make it a question whether the digestion was not in fact more nearly complete than even these figures make it. An interesting series of experiments in artificial digestion conducted by Dr. R. D. Clark, in behalf of the New York Dairy Commission, though of course not affording a definite measure of the process as it actually goes on in the body, accords with the very natural supposition that, in ease, and perhaps in completeness of digestion, oleomargarine would rank between butter and the fat of ordinary meat.

In chemical composition oleomargarine stands between meat-fat and butter. It will be remembered that oleomargarine is made from beef-fat and lard by removing from them part of the stearin, which counts as the least digestible ingredient, and adding a little butter and sometimes oil, as cotton-seed oil. The bulk of all these fatty substances, meat-fat, butter, and oil, consists of the same or nearly the same kinds of fat, the meat-fat having the more stearin. The butter, however, contains small quantities, seven per cent. or thereabouts, of peculiar fats, butyrin, caproin, etc., which give it its flavor and which are thought by some to make it more easily digestible, especially by persons whose digestion is enfeebled by lack of digestive juices or otherwise.

In the excitement over oleomargarine legislation, the discussion of the relative digestibility of butter and butter substitutes has been made very active by the importance of its bearing upon their comparative values for nutriment, and many statements have been made as to the effect of the chemical composition of the peculiar butter-fats and the consequent chemical changes in the process of digestion and assimilation in the body. It is interesting to compare the very positive inferences which some writers upon the subject draw from experimental investigations, with the very guarded expressions of opinion made by the authors of the same investigations in their writings and in personal conversation. The facts at hand and the general impression of special students of these subjects, so far as I have observed, are to the effect that probably, for healthy persons, the difference between butter and oleomargarine in ease and in completeness of digestion would be at most very slight, but that for people with enfeebled digestion and for infants, butter may, perhaps, at times, have the advantage.

When we consider that the quantity of butter which one would naturally use on a slice of bread would, roughly speaking, be about as large as that of the fat which would remain in a corresponding slice of lean, juicy beef after the larger particles of fat had been trimmed off, it is hard to believe that the difference in digestibility or nutritive value between the butter and the same quantity of oleomargarine could be of very great moment.

Some of the food-materials referred to in the table on page 735 and in the diagram as meat, bread, and milk, have been tested, each by several experiments with more than one person. With others, as eggs, corn-meal, rice, pease, and potatoes, only a single trial has been made. Doubtless, extended series of tests would give averages differing more or less from these figures. Another thing that makes the results a little uncertain is that some of the food-materials may perhaps be more completely digested when taken in small quantities with other materials, in the ordinary way, than when so much of them is eaten and without any other food. These and other sources of slight error make more extended experiments very desirable. I should add that the figures for mackerel, in the diagram, are only estimates, based upon experiments with haddock (the only kind of fish that has been tested experimentally), and with meats.

EFFECTS OF DIFFERENT CIRCUMSTANCES UPON THE DIGESTION OF FOOD.

THE estimates in the table and diagram apply to the quantities of nutrients digested, from wholesome and properly cooked and masticated food, by healthy persons. But the ease and time of digestion and the fitness of the digested matters for the user, are likewise very important considerations, and these as well as the proportions digested are more or less affected by the preparation of the food, the quantity consumed, and the materials eaten and drunk with it; by exercise and sleep; and by the bodily condition or peculiarities of digestive function of the person.

The effect of the preparation of food, especially of its cooking, is one of the many topics about which one can write with a freedom and fluency inversely proportional to his understanding of the known facts. The chief underlying principle is the same as in the dissolving of the ore of which I spoke above. If the particles of ore are large, the acid will act upon them very slowly. Stirring would hasten the solution of the soluble materials. Time would be needed for those that were slow to dissolve. So in the digestion of food, we cut our meat into small pieces and chew it into still finer ones; and the grains of wheat, which we cannot well chew, are first ground in the mill. Milk requires neither cooking nor chewing. Its nutrients are either already in solution or in very minute particles, it has no starch to be changed into sugar by the ptyalin or saliva, its only carbohydrate, milk sugar, being already a sugar and soluble; and we accordingly drink it raw. Ordinary meats are found by experiment to be digested as readily or even more readily when taken raw than when cooked, provided they are properly masticated, *i. e.*, finely chewed. But we like their taste better, and hence are more inclined to masticate them properly, when well cooked.

Some interesting experiments on the rapidity of digestion of meats cooked and uncooked, and of milk, have been lately conducted by Herr Jensen, in the laboratory of the University of Tübingen. To test the effect of cooking, he took lean beef, chopped it fine, and separated the tendons and other connective tissue as completely as he could. A portion was left raw, other portions were boiled, and still others were roasted. Of the boiled and roasted portions, some were rare, or, as Herr Jensen called them, "half done," and others well done. The raw, half done, and well done portions were tested by artificial digestion with pepsin, by experiments in the stomach of a dog, and by experiments in the stomach of a healthy man.

In the experiments by artificial digestion Herr Jensen put the meat in glass tubes, poured a solution containing pepsin upon it, and kept the tubes with their contents in a warm place, at about the temperature of the body, for twenty-four hours, stirring the mixtures from time to time, thus imitating the operation that goes on in the stomach. The dog with which the experiments were made had metal tubes permanently inserted through the skin into the stomach, which could be opened or kept closed with a stopper at will. (I may remark in passing that a dog thus provided with a stomachic fistule is regarded as a very convenient item in the list of appliances of a physiological laboratory, and my limited observation of the behavior of the animals has left with me the decided impression that such ways of being useful to the world in their day and generation are much less distasteful to them than many anti-vivisectionists would have us think.) The meat was inclosed in a cloth, inserted through the tube, and removed after the desired time. In the experiments with the man, a laboratory servant, the food was taken into the stomach when the latter was empty, and, after digestion for the desired time, withdrawn by a stomach-pump.

The experiments all told nearly the same story. The raw meat was digested more readily than the cooked. In the trial by artificial digestion the residues unaltered by the pepsin were smallest with the raw meat and largest with that which had been most thoroughly cooked by boiling or roasting. In those with the man, the digestion was completed in different lengths of time, as set forth in the figures herewith, which I translate from Jensen's report.

The beef	*was digested in*
Raw	2 hours.
Boiled, "half done"	2½ "
Boiled, "well done"	3 "
Roasted, "half done"	3 "
Roasted, "well done"	4 "

In like manner, boiled milk required a somewhat longer time for digestion than milk not boiled.

These results and those of other experiments, though not to be taken as an exact measure of the digestibilities of the substances in a healthy stomach, are still the more worthy of confidence because they accord with the chemistry of the subject. But we must remember that they apply only to what takes place in the stomach; while the normal process of digestion goes on in the intestine after the food has left the stomach.

Some kinds of meat are very tough when raw and are made more tender by cooking. This is due, in part at least, to changes in the so-called connective tissue. The connective tissue of bone, tendons ("gristle"), hoofs, etc., is disintegrated and changed into gelatine or glue by steaming or boiling. In like manner, the minute portions of this material that are distributed through the meat, are softened and lose their tenacity, and thus tough meat is often made tender. But to do this, and to cook meat sufficiently, requires less heat and less outlay for fuel than many people suppose. A great saving can often be made by use of proper devices for cooking, as I hope to explain at another time.

Vegetable foods often require cooking to fit them for use. This is especially true of starchy foods, such as grains, wheat, corn, etc.; beans and pease; and potatoes. The starch is contained in cells. The outer covering of the cell is cellulose (woody-fiber), the material which constitutes the fiber of cotton and linen and which is used to make cloth and paper. If the particles of ore above referred to were incased with material which the acids could not easily penetrate, they would be very slow to dissolve. The digestive juices of the human body act very slowly upon cellulose, and for this reason the starch of raw potatoes or uncooked grain would be difficult of digestion. But in cooking, the little sacs of starch are burst open and the starch itself undergoes more or less chemical change, so that the ptyalin and other agents convert it much more readily into sugar or other digestible forms. But to get at the matter of the changes of food in cooking requires more discussion of the chemical principles involved than would be proper here.

In brief, so far as animal foods are concerned, cooking is mainly a device to gratify the palate, but many vegetable foods require heating, with or without water, to fit them for use by man.

As to the effect of the quantity of food upon the proportion digested, the experiments at hand seem to point to the interesting conclusion that when a moderate amount is taken, it is digested more completely than a very large or, at times, even a very small quantity. So, likewise, a moderate amount of water seems favorable, while too much has been found to interfere with digestion.

A great deal is said and written about the effect exerted upon the digestion of food by food-adjuncts, such as spice, mustard, and other flavoring materials; beef-tea and meat-extract; tea, coffee, chocolate, and similar beverages; and alcoholic drinks. Instead of venturing an opinion upon the subject which is rather physiological than chemical, I may more appropriately quote one of the latest authoritative utterances upon the subject. Professor Forster, a well-known experimenter, in speaking of what the Germans call *Genussmittel*—appetizers is perhaps the nearest corresponding word we have — the materials which we take with our food either for their own agreeable flavor or to improve the flavor of the food, and which are often supposed to help the digestion,— says in substance as follows:*

> "There is no doubt that the human digestive apparatus can be excited to activity in various ways with *Genussmittel*, including such as are used by man in a refined civilization, at the beginning and end of his meals, *e.g.*, meat broth, salt and salt condiments like caviar, cheese, etc. . . . We know that when brought into contact with the mucus membrane of the stomach and intestines of a living animal, they cause the filling of the blood-vessels and secretion of the digestive juices. Sugar and salt are hardly brought into the mouth before they excite abundant effusion of saliva. Indeed, the same effect is produced even by the sight or smell of savory foods, and some of the well-tasting substances may act upon the digestive apparatus and its glands by simply being taken into the blood circulation. Thus I have observed experimentally a rich secretion of gall after an injection of a solution of sugar into a vein (vena mesenterica). . . . It is very natural to infer from this that the work of digestion will go on better with the aid of such condiments than without them, in two ways: either more nutriment might be digested from the same food, or, if there were no increase in the amount digested, it might be digested more quickly with their help, which would likewise be a gain. . . . But, important as this may seem to physiologists, it is of minor consequence with healthy persons. Thus, in experiments made with a man under my direction, meat which had been treated with water [to remove the 'extractives' which give meat its flavor and which are the chief constituents of beef-tea and meat-extract] and was so tasteless as to be eaten in any considerable quantity only with difficulty, the quantity digested and observed to pass into

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* In the volume on "Ernährung and Nahrungsmittel," of Pettenkofer and Ziemssen's "Handbuch der Hygiene," the latest standard German work on these subjects.

the circulation was as large as with the same weight of meat roasted in the ordinary way; and both Bischoff and Hofmann have found that meat-extract taken with bread or with a mixed diet did not materially affect the digestion. And in experiments by Flügge with a mixed diet so tasteless as to make it, when continued some time, extremely repugnant, so that great effort was required to eat it, the digestion seemed to be unaffected thereby.

"For the sick and convalescent, on the other hand, the effect of these appetizers upon the digestion is of great importance, especially where the digestive apparatus has been for a time more or less inactive and requires stimulating. Thus the observations of Kemmerich show the usefulness of bouillon and meat-extract in case of enfeebled digestion."

In the case of the ore there must be plenty of acids or it cannot dissolve. If the supply of digestive juices is insufficient, the food cannot digest. The chief use of these food-adjuncts would seem to be to stimulate the production of digestive juices. The results of later experimental research and the teachings of the physiologists whose opinions are most valued among their fellow-specialists seem, so far as I can gather, to be in the same line with the statements here quoted. It would thus appear that, while the materials which we call appetizers may often be very helpful where digestion is enfeebled, they are, for healthy people, superfluous and without special effect upon the utilization of food in the body. As regards the stronger stimulants, especially alcohol, the same class of physiologists, so far as I can gather from their writings and from personal conversation, are, in general, rather cautious in speaking of its effect upon digestion, but are nevertheless inclined to believe that it does under some circumstances help the digestion of food. There are experiments which indicate that alcohol, taken into the stomach in considerable quantities, may retard gastric digestion while it remains there, but that, on the other hand, it has a stimulating action upon the secretion of the digestive juices, so that it may materially aid digestion. Indeed, just as I write, a German journal brings account of late experiments by Gluzinski which accord with this view. That, when taken in moderate quantities, alcohol should thus help weak digestion, would, unless I err, be quite in accord with the best experimental testimony and with a common opinion of experimenters. Some of our strong temperance friends would hardly second Paul's advice to Timothy to "use a little wine for thy stomach's sake," but the experimental physiologists seem to side with Paul. But, decidedly as thoughtful specialists may reject the extreme statements of some temperance agitators, many of them are very emphatic in their declarations concerning the danger of excessive use of alcohol and the evil which results from it.

Regarding the effect of moderate exercise just after eating, observations differ, some experiments indicating that muscular labor retards digestion, others that it does not. During sleep digestion has been found to be diminished. To consider the connection between the mental and physical condition and digestion would take us too far from our present purpose.

To recapitulate. In considering the digestibility of food we have to take into account (1) the quantity digested, and (2) the ease and time of digestion. As regards the quantities digested from reasonable amounts of ordinary food-materials by healthy people, the best experimental evidence indicates that:

First. The protein of our ordinary meats and fish is very readily and completely digestible.

Second. The protein of vegetable foods is much less digestible than that of animal foods. Of that of potatoes and beets, for instance, a third or more may escape digestion and thus be useless for nourishment.

Third. Much of the fat of animal food may at times fail of digestion.

Fourth. The carbohydrates, starch, sugar, etc., which make up the larger part of vegetable foods, are very digestible.

Fifth. The animal foods have in general the advantage of the vegetable foods, that they contain more protein, and that their protein is more digestible.

Sixth. The quantities digested appear to be less affected by flavor, flavoring materials, and food-adjuncts than is commonly supposed.

Concerning the ease and time of digestion, and consequent comfort and health, the lack of accurate experimental data renders it more difficult to make concise statements. Cooking and other conditions are very important. Very much depends upon the individual peculiarities of different people.

W. O. Atwater.

WOMAN AND ARTIST.

I THOUGHT to win me a name
  Should ring in the ear of the world! —
How can I work with small pink fists
  About my fingers curled?

Then adieu to name and to fame!
  They scarce are worth at the best
One touch of this wet little, warm little mouth
  With its lips against my breast.

Alice Williams Brotherton.