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AN EXPERIMENTAL INQUIRY REGARDING THE NUTRITIVE VALUE OF ALCOHOL.

BY

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Presented to the Academy by JOHN S. BILLINGS.

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AN EXPERIMENTAL INQUIRY REGARDING THE NUTRITIVE VALUE OF ALCOHOL.

BY W. O. ATWATER AND F. G. BENEDICT.

INTRODUCTION.

The present report gives the details of a number of metabolism experiments with men, in which the effects of diet with and without alcohol have been compared.[a] The details of a number of digestion experiments, which form part of the same investigations, have also been included.

PURPOSE OF THE EXPERIMENTS.

The main purpose of the experiments has been to get light upon the effects of alcohol in the diet, with especial reference to the question of its nutritive value.

Food is used in the body to build and repair tissue and to furnish energy. Only the nitrogenous compounds (protein) of the food serve the first purpose; they also serve as a source of energy, but the main supply of energy is obtained from the fats and carbohydrates. The fuel ingredients may be burned at once or may be stored for future use.

Alcohol contains no nitrogen and therefore can not build or repair tissue; it is rather to be classed with the fats and carbohydrates, and if it has any food value, this must be as a fuel. It does not appear to be stored for any considerable time, but is disposed of soon after it is taken into the body.

Alcohol, however, differs from the protein, fats, and carbohydrates of food materials in that it may exert, and when taken in large enough doses does exert, an indirect action upon the brain and nerves and through them upon the nutritive and other processes to which the general term metabolism is applied. In this way its actual value may be either increased or diminished according as it aids or hinders digestion, or either accelerates or retards metabolism. We have then to consider not only its direct action as nutriment for the supply of energy, but also its indirect action upon the metabolism and utilization of other food. In the experiments here

[a]The inquiry was undertaken at the instance of the Committee of Fifty for the Investigation of the Drink Problem. The experimental work was done in the chemical laboratory of Wesleyan University. A large share of the expense was borne by the committee of fifty although contributions were also received from the Elizabeth Thompson and Bache funds and from private individuals. The experiments were parallel with others of similar character, which are conducted under the auspices of the United States Department of Agriculture. These latter experiments form a part of a general inquiry regarding the food and nutrition of man, which is authorized by Congress and prosecuted in different parts of the United States. The special inquiry into the nutritive action of alcohol was made possible by the generosity of Wesleyan University, which offered to the committee of fifty the use of laboratory and other facilities that have been made available to the Department of Agriculture and the Storrs Experiment Station for nutrition inquiries.

The investigation has been pursued with the active cooperation of a number of gentlemen, including especially Mr. A. P. Bryant, under whose direction the computations of the results have been made, and Mr. A. W. Smith, Dr. O. F. Tower, and Dr. J. F. Snell, all of whom have been intimately associated with the elaboration of the apparatus and methods. Mr. Smith and Dr. Snell served as subjects in several of the experiments reported beyond, though the subject of the larger number was Mr. E. Osterberg.

The details of the experiments without alcohol and of two of those with alcohol, Nos. 7 and 10, have been published in bulletins of the United States Department of Agriculture as stated beyond.

described the indirect action of alcohol has been studied only in so far as (1) through its influence upon the secretion of digestive juices or otherwise it has tended to increase or diminish the proportion of the other food digested, or (2) it has increased or decreased the metabolism of other food or body material.

The ulterior effects of alcohol do not come within the scope of this particular inquiry, which is limited to its use by the body as nutriment.

THE QUESTIONS ACTUALLY STUDIED.

It appears then that whatever value alcohol may have for nutriment must depend upon its ablity to serve as fuel for furnishing energy to the body. Accordingly the main question proposed for study is this: What is the value of alcohol for fuel and how does it compare in this respect with sugar, starch, fats, and other nutrients of ordinary food materials? A collateral question is the effect of alcohol upon the proportions of nutrients digested from the food with which it was taken.

Experimental research has shown several ways in which the ingredients of ordinary food and body material serve as fuel. They are oxidized in the body; in the oxidation, their potential energy becomes kinetic and is thus made useful to the body; part of this kinetic energy appears as heat; another part appears as muscular work; in yielding energy by its own oxidation, food protects the material of the body and of other food from consumption. We have then to consider how alcohol compares with the ordinary fuel ingredients of the food in these ways.

It is clear that the main problem is that of the metabolism of energy in the body. Accordingly, while the experiments here described bear upon the use of alcohol in each of the ways just mentioned and upon collateral topics also, the fundamental question studied has been this: To what extent is the energy of alcohol transformed and utilized in the body like the energy of the nutrients, especially the fats and carbohydrates, of ordinary food materials?

In studying these questions we go down to one of the fundamental principles of material science. The plan of the whole inquiry is based upon the principle that the chemical and physical changes which take place in the body, and to which the general term metabolism is applied, occur in obedience to the laws of the conservation of matter and energy. That the law of the conservation of matter applies within the living organism, no one would question. It might seem equally certain that the metabolism of energy within the body takes place in accordance with the law of the conservation of energy. In experiments with men in the respiration calorimeter described beyond, the close agreement between the income and the outgo of energy in the body, under various conditions of work and rest, may be regarded as practically demonstrating that the law holds in the living organism. Such demonstration had, indeed, been approximated by earlier investigations, notably those of Rubner with dogs.

APPARATUS AND METHODS OF INQUIRY.

The experiments here described were made with a respiration calorimeter especially devised for research of this kind. The apparatus serves to measure the materials received and given off by the body, including the products of respiration, and is thus a "respiration apparatus." It also serves to measure the heat given off by the body and hence is a form of calorimeter. To indicate this twofold purpose it is called a "respiration calorimeter." The apparatus and methods of its use have been described elsewhere;[a] a brief description will suffice here.

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[a] In the following bulletins of the Office of Experiment Stations of the United States Department of Agriculture: No. 44, Report of Preliminary Investigations on the Metabolism of Nitrogen and Carbon in the Human Organism with a Respiration Calorimeter of Special Construction, by W. O. Atwater, Ph. D., C. D. Woods, B. S., and F. G. Benedict, Ph. D.; No. 63, Description of a New Respiration Calorimeter and Experiments on the Conservation of Energy in the Human Body, by W. O. Atwater, Ph. D., and E. B. Rosa, Ph. D., pp. 94; No. 69, Experiments on the Metabolism of Matter and Energy in the Human Body, by W. O. Atwater, Ph. D., and F. G. Benedict, Ph. D., with the cooperation of A. W. Smith, M. S., and A. P. Bryant, M. S., pp. 112; No. 109, Further Experiments on the Metabolism of Matter and Energy in the Human Body, by W. O. Atwater, Ph. D., and F. G. Benedict, Ph. D., with the cooperation of A. P. Bryant, M. S., A. W. Smith, M. S., and J. F. Snell, Ph. D.

The chamber of the apparatus is so arranged that a man may spend a number of days in comparative comfort within it. It is lighted by a window, and is furnished with a folding chair, table, and bed, and, when the experiment involves muscular work, with a stationary bicycle also. The chamber is ventilated by a measured current of air, samples of which are taken for analysis before it enters and after it leaves the chamber. In this way the products of respiration are determined. Provision is also made for weighing, sampling, and analyzing all the food and drink, and the solid and liquid excreta as well. By comparing the chemical elements and compounds received by the body in food, drink, and inhaled air with those given off in the solid, liquid, and gaseous forms by the intestines, kidneys, lungs, and skin, it is possible to strike a balance between the total income and the total outgo of matter in the man's body. This serves as the measure of the metabolism of matter in the body.

In addition to this the metabolism of energy is also studied. To this end it is necessary to determine the potential energy of the food and drink taken into the body and of the solid and liquid excreta given off by the body, as well as the amounts of energy given off in the form of heat, external muscular work, and otherwise. The measurements of the potential energy of the food and excreta are made with the bomb calorimeter.[a] The determination of the heat given off from the body is made by certain arrangements in connection with the respiration calorimeter. A current of water passing through a special coil of pipes suspended in the chamber absorbs the heat that is generated within it, and by measuring the quantity of water that passes through the coil and its rise in temperature the amount of heat absorbed may be determined. To this is added the latent heat of the water vaporized within the chamber.

So delicate are the measurements of temperature that the observer sitting outside and recording the changes every two or four minutes immediately detects a rise or fall of even one one-hundredth of a degree in the temperature of the inner copper wall or of the air inside the chamber. If the man inside rises to move about, the increase in the heat given off from his body with this muscular work shows itself in a rise of temperature which is immediately detected.

In the work experiments the subject spends a certain portion of each day in muscular exercise upon an apparatus arranged as an ergometer, by which the amount of muscular work done may be measured. The ergometer consists of a stationary bicycle connected with a dynamo by which the power which the rider applies to the pedals, and which is not changed to heat by the friction of the machine, is converted into an electric current, which is passed through an electric lamp and is in turn changed to heat. The ergometer is arranged to measure the amount of muscular work done, in terms of heat, by determinations of the amount of energy converted into heat by friction and the amounts of electric current generated and changed to heat.

From the energy of food, drink, solid and liquid excretory products, and body material stored or lost the net income of energy may be computed. The net outgo is measured by the apparatus. By comparing these the balance of income and outgo of energy is found.

The data obtained as explained above, taken in connection with what is known of the physiological processes that go on in the body, give more accurate information than can be otherwise obtained regarding the ways in which the food is used in the body and the quantities of food ingredients that are needed to supply the demands of the body for the various purposes of work and rest and the comparative nutritive value of different food materials.

ACCURACY OF APPARATUS AND METHODS.

Two methods of testing the accuracy of the apparatus are employed. By one method known amounts of heat are generated electrically within the chamber, and the heat is measured by the apparatus. In this way its accuracy as a calorimeter only is tested. By the second method known amounts of ethyl alcohol of known purity and composition are burned completely within the chamber, and the amounts of water, carbon dioxide, and heat resulting from the combustion of alcohol are determined by the apparatus. In this way its accuracy both as a respiration apparatus and as a calorimeter is tested. In the average of five electrical tests the amount of heat

[a] For description of the bomb calorimeter see U. S. Dept. Agr., Office Expt. Stations, Bul. 21, pp. 120–126, and Storrs Conn. Experiment Station Report, 1897, p. 199.

measured by the calorimeter was 100.01 per cent of the amount generated by the electric current. The averages of the results obtained in seventeen alcohol tests are summarized in the following table:

Summary of results of tests in which alcohol was burned in the calorimeter.

	Carbon dioxide.	Water.	Heat.
	Grams.	*Grams.*	*Calories.*
Amount required	19, 239. 8	12, 264. 4	64, 554. 1
Amount found	19, 206. 9	12, 379. 1	64, 513. 3
	Per cent.	*Per cent.*	*Per cent.*
Ratio of amount found to amount required	99. 8	[a] 100. 9	99. 9

[a] After the completion of the later experiments a slight leak was found in the "valve box" through which the outgoing air current passed on its way to and from the "freezers," and by which water, condensed on the outside, may have entered. There is every reason to believe that the quantity of water actually found was thus made too large by a fraction of 1 per cent. In the average of the first nine experiments the amount of water found was 100.6 per cent of that required. As an alcohol check test was generally made between each two metabolism experiments or series of experiments we have a means of knowing when the leak began to effect the results and the amount of the error introduced. See Bulletin 109 of the Office of Experiment Stations, above referred to.

The results thus indicate that the respiration calorimeter is an instrument of precision and that the determinations of carbon dioxide, water, and heat produced within the chamber of the respiration calorimeter are sufficiently accurate for experiments with the living subject.

THE EXPERIMENTS.

GENERAL PLAN.

For the subjects of the experiments men were selected who were in good health, had apparently normal digestion, and did not find the confinement in the chamber uncomfortable. A diet was chosen which provided materials as palatable and in as much variety as was consistent with convenient preparation, and with accurate sampling and analysis. The quantity and composition of the diet were generally such as to maintain the body nearly in nitrogen and carbon equilibrium under the conditions of the experiment, whether of work or of rest. In 13 of the experiments the diet included alcohol.

The alcohol amounted in general to about 72 grams (2½ ounces) a day, or as much as would be contained in a bottle of claret or 3 or 4 glasses of whisky. In most cases pure (ethyl) alcohol, but in some whisky or brandy was used. It was mixed with either water or coffee, and was given in 6 small doses, 3 with meals and the rest at regular intervals between, in order to avoid as far as possible any effect upon the nerves. The alcohol supplied not far from 500 calories of energy. In the experiments without external muscular work, the total energy of the diet was about 2,500 calories, so that the alcohol furnished one-fifth of the total energy. In the experiments in which the man was engaged in more or less active muscular work, the total energy of the food was larger, averaging about 3,900 calories, so that the alcohol furnished between one-seventh and one-eighth of the total energy of the diet.

In order that the subject might become accustomed to the diet and reach approximate nitrogen equilibrium with it before the experiment proper began, a preliminary digestion experiment of at least 3 days immediately preceded the metabolism experiment. Any change of diet found desirable or necessary was made during this period, and the preliminary experiment was continued until nitrogen equilibrium was supposed to be more or less nearly reached. In most cases the preliminary experiment continued 4 days. During this period the subject was, in general, engaged in his customary occupation, but conformed his muscular activity more or less to that of the coming experiment. Thus if it was to be a work experiment, he rode a bicycle or walked a considerable distance each day. If it was to be a rest experiment, he avoided all unnecessary exercise. For supper on the last day of this preliminary digestion experiment about .3 of a gram of lampblack was taken in a gelatin capsule with the food, in order to mark the separation of the feces of the preliminary experiment from those of the metabolism experiment proper. The subject entered the chamber about 7 o'clock on the evening of the last day of the preliminary digestion period and retired about 11 o'clock. At about 1 o'clock in the morning the heat measurements were begun.

The night sojourn in the chamber sufficed to get the temperature of the apparatus and its contents of carbonic acid and water into equilibrium, so that accurate measurements might begin at 7 o'clock on the first morning of the experiment proper. In some cases the experiment continued only 4 days; in other cases the experimental period consisted of 6 or 9 successive days spent within the apparatus, the entire period being divided into 3 experiments of 2 or 3 days each with changes in the diet as hereafter explained. The determinations of carbon dioxide, water vapor, and heat were made in 6-hour periods, so that complete data for an experiment showed the total amounts of these compounds given off from the body during the periods ending at 1 p. m., 7 p. m., 1 a. m., and 7 a. m. of each day of the experiment. As noted beyond, the urine was also collected and its nitrogen content determined for corresponding periods.

The daily routine of the subject within the chamber was indicated by a programme made up before the beginning of the experiment. A copy of the programme was furnished to the subject, who followed it with reasonable closeness, and other copies were posted in convenient places outside the apparatus for the benefit of those who had the experiments in charge.

Much care was necessarily taken in preparing the food materials selected for the diet and in taking samples for analysis. With the exception of milk and alcohol, the proper quantity of each kind of food, either for each meal or for the whole day, was put up in glass jars before the experiment began; and materials which might spoil during the course of the experiment, such as bread and meat, were thoroughly sterilized.

Special arrangements were made by which the mixed milk from a definite number of select cows was supplied for each experiment. But even with this precaution, the milk was not entirely uniform in composition from day to day.

The handling of the alcohol was much simpler. A quantity sufficient for several experiments was procured and analyzed, and the proper amounts were drawn each day as needed.

As stated above, the separations of the feces for each experiment were made by means of lampblack. The total feces for each experiment were analyzed, and the average per day used in the computations of results. It was assumed that when the food and exercise were so nearly uniform the undigested residues and metabolic products would not vary greatly from day to day, and such irregularities as might occur would hardly affect the average for an experiment.

The urine was collected in 6-hour periods, and the amount, specific gravity, and nitrogen determined for each period. Aliquot portions of the urine of the 6-hour periods were taken for preparation of a composite sample for the day, and in like manner aliquot portions of the composite sample of urine for each day were taken for the preparation of a sample for the whole experiment or series of experiments. The nitrogen and heat of combustion were determined in the urine for each day and in the composite for the whole experiment. The carbon and hydrogen were determined in the composite sample of urine for the whole experiment or series of experiments, and were divided among the different days in proportion to the amount of nitrogen.[a]

THE MEN WHO SERVED AS SUBJECTS OF THE EXPERIMENTS.

Three different men, E. O., A. W. S., and J. F. S., have served as subjects in these experiments. Each of these, when not sojourning in the apparatus, was engaged in work connected with the investigations. E. O. was a general assistant in the chemical laboratory, a Swede by birth, who had been a number of years in this country; he was 32–33 years old, and weighed about 155 pounds. Since boyhood he had been accustomed to the moderate use of alcoholic beverages. A. W. S. was a physicist, a native of New England, 25 years old, and weighed

[a] For further explanation, see U. S. Dept. Agr., Office Exp. Stations, Bul. 69, pp. 21 and 35.

about 155 pounds. J. F. S. was a chemist, a Canadian by birth, 29 years old, and weighed about 150 pounds. The last two had always been total abstainers. The subjects were weighed without clothing.

SYMPTOMS OBSERVED IN EXPERIMENTS WITH ALCOHOL.

In deciding upon the daily amount of alcohol and its division into doses, the purpose was to give the subjects as much as they could well take without apparent nervous disturbance. As above stated, the quantity of absolute alcohol, about 72 grams per day, was divided into 6 nearly equal doses, of which 3 were taken with the meals and 3 between meals. It supplied about one-fifth of the total energy of the diet in the rest experiments and about one-seventh in the work experiments. On one or two occasions J. F. S. experienced a slight tingling in the ears immediately after drinking the alcohol. On one occasion E. O. complained of a slight feeling of dullness. On one occasion A. W. S. thought he experienced a very slight dizziness. Otherwise neither one was at any time aware of any especial effect of the alcohol upon the sensations in any way. With the exception of the tingling in the ears noticed by J. F. S., it is not certain that any of the symptoms referred to were due to the alcohol.

As regards the effect of alcohol upon the body temperature and pulse rate in these experiments there is little to be said. The only observations made were those by the subjects themselves, and the difficulty of accurately determining one's own normal pulse rate is well known. The observations of temperature were made with a clinical thermometer in the mouth or axilla by the usual method, which of course does not show the exact average internal temperature of the body. The data obtained with E. O. and A. W. S. were not sufficiently accurate and numerous to be decisive. The observations by J. F. S. were made at frequent intervals and with considerable care. The results imply a slightly decreased body temperature and increased pulse rate in the experiments with alcohol diet as compared with those with ordinary diet, but the differences are not large.

The data as observed are recorded in the tables in the appendix.

GENERAL DESCRIPTIONS OF INDIVIDUAL METABOLISM EXPERIMENTS.

The data of the experiments with alcohol are given in detail in the appendix beyond. The results are summarized, and brief descriptions of the experiments are given on the following pages. The results of these experiments are here compared with those of similar experiments without alcohol, the details of which are published elsewhere, as indicated in Table 1, which follows.

LIST OF METABOLISM EXPERIMENTS WITH AND WITHOUT ALCOHOL, AND GROUPING FOR COMPARISON.

Of the metabolism experiments with men in the respiration calorimeter, 13 had for one of their objects the study of the nutritive value of alcohol. The details of 11 of these are given in the present report; those of 2 others have been published elsewhere. These 13 experiments are compared with a like number made with the same men, but without alcohol in the diet. Table 1 gives a list of these 26 experiments, with grouping for comparison and references to publications in which the details may be found.

TABLE 1.—*List of the experiments, and grouping for comparison of results with and without alcohol.*

	Group.	No.	Date.	Duration.	Subject.	Nature of the experiment. Rest or work.	Nature of the experiment. Ordinary or alcohol diet.	Protein in food.	Energy in food.	Place of publication of details.
				Days.				*Grams.*	*Calories.*	
More strictly comparable.	A	9	Jan. 10–14, 1898	4	E. O.	Rest	Ordinary	119	2,717	(a)
		10	Feb. 15–19, 1898	4	do	Rest	Alcohol	123	2,709	(a)
	B	24	Mar. 19–22, 1899	3	do	Rest	Ordinary	124	3,061	(b)
		22	Mar. 13–16, 1899	3	do	Rest	Alcohol	124	3,044	(c)
	C	26	Feb. 14–17, 1900	3	J. F. S.	Rest	Ordinary	100	2,490	(b)
		28	Feb. 20–23, 1900	3	do	Rest	do	99	2,489	(b)
		27	Feb. 17–20, 1900	3	do	Rest	Alcohol	99	2,491	(c)
	D	11	Mar. 22–26, 1898	4	E. O.	Work	Ordinary	124	3,862	(b)
		12	Apr. 12–16, 1898	4	do	Work	Alcohol	121	3,891	(c)
	E	29	Mar. 16–19, 1900	3	J. F. S.	Work	Ordinary	100	3,487	(b)
		31	Mar. 22–25, 1900	3	do	Work	do	100	3,495	(b)
		30	Mar. 19–22, 1900	3	do	Work	Alcohol	99	3,458	(c)
	F	32	Apr. 20–23, 1900	3	do	Work	Ordinary	101	3,487	(b)
		34	Apr. 26–29, 1900	3	do	Work	do	100	3,493	(b)
		33	Apr. 23–26, 1900	3	do	Work	Alcohol	100	3,486	(c)
Less strictly comparable.	G	13	Nov. 8–11, 1898	3	E. O.	Rest	Ordinary	117	2,596	(b)
		14	Dec. 20–24, 1898	4	do	Rest	do	94	2,513	(b)
		7	June 8–12, 1897	4	do	Rest	Alcohol	104	2,462	(a)
	H	5	May 4–8, 1897	4	do	Rest	Ordinary	119	2,655	(a)
		15	Jan. 16–18, 1899	2	do	Rest	Alcohol	109	2,653	(c)
		16	Jan. 18–20, 1899	2	do	Rest	do	109	2,653	(c)
		17	Jan. 20–22, 1899	2	do	Rest	do	109	2,653	(c)
	I	21	Feb. 12–15, 1899	3	A. W. S.	Rest	Ordinary	97	2,264	(b)
		18	Feb. 6–8, 1899	2	do	Rest	Alcohol	97	2,776	(c)
		19	Feb. 8–10, 1899	2	do	Rest	do	97	2,776	(c)
		20	Feb. 10–12, 1899	2	do	Rest	do	97	2,776	(c)

[a] U. S. Dept. Agr., Office Expt. Stations, Bul. 69, on "Experiments on the Metabolism of Matter and Energy in the Human Body," by W. O. ATWATER, F. G. BENEDICT, and Associates.

[b] U. S. Dept. Agr., Office Expt. Stations, Bul. 109, on "Further Experiments on Metabolism of Matter and Energy, 1898–1900," by ATWATER, BENEDICT, and Associates.

[c] The present memoir.

The experiments are divided into groups, each group including experiments with and without alcohol, but made with the same subject. In some groups there are only two experiments, one with alcohol and one with ordinary diet; in others there are more than one experiment either with or without alcohol.

More and less strictly comparable experiments.—In the first 6 groups, A to F, inclusive, the experiments with and without alcohol were practically duplicates in duration, muscular activity, and amounts of protein and energy in the diet, the main difference being that a part of the fats and carbohydrates of the ordinary diet, enough to supply in general about 500 calories of energy, was replaced by the isodynamic amount of alcohol. In the 3 groups, G to I, which include a number of the earlier experiments, those with and without alcohol were not so nearly duplicates. In some instances the difference was unintentional, and was due to a difficulty in obtaining food materials of like composition at different times. In these cases it was not found practicable to complete the analyses long enough in advance of the experiments to insure uniformity of diet as regards amounts of protein and energy. Later, means were devised for putting up food materials in considerable quantities and preserving them by canning or cold storage, so that the amounts of protein and energy in the diet were made more nearly the same in experiments separated by longer or shorter intervals of time. Accordingly the experiments of groups A to F are designated as more directly comparable and those of Groups G to I as less directly comparable.

Order of arrangement of experiments with and without alcohol.—In these experiments two different orders of arrangement have been observed. By one plan the experiments with and without alcohol are separated by a longer or shorter interval, and in each case the experiment proper, during which the subject is in the respiration calorimeter, is preceded by a preliminary period during which he is outside the chamber but has the same or nearly the same diet and exercise. The experiments of Groups A, B, D, G, and No. 5 of Group H belong to this class. Each of these experiments has continued in the majority of cases for 8 days, the first half being devoted to the preliminary and the other half to the actual experimental period. In some instances, however, the preliminary period was only 3 days. One object of the preliminary period has been to bring the body as nearly into nitrogen equilibrium as practicable. The attempts to secure nitrogen equilibrium by this means have not, on the whole, been successful, a circumstance to which more especial attention is called beyond.

By the other plan the experiments with and without alcohol follow one another without interruption, thus making really successive periods of a single experiment, or successive experiments of a series. Each such series is preceded by a preliminary experiment, during which the man is not in the chamber, but receives, at least during the latter part of the period, the same diet as in the experiment proper. At the end of the preliminary period the man enters the chamber and remains there during the several periods of the experiments proper. The transitions from one diet to another are thus immediate. The experiments of Groups C, E, F, and I and Nos. 15, 16, and 17 of Group H were of this sort. Since, however, No. 15 was preceded by a preliminary period, and the only differences between Nos. 15, 16, and 17 were in the kind of alcoholic beverage—commercial alcohol, whisky, and brandy—these might be considered one experiment of the first kind.

Each plan has its advantages and disadvantages. A reason for this is found in the fact that alcohol in moderate quantities appears to have, with some persons, especially with those unaccustomed to its use, a special effect upon nitrogen metabolism. It seems probable that this is exercised through the nervous system, that it may for a short time tend to increase the excretion of nitrogen, but that it is, in some cases at any rate, only temporary, and disappears after a few days when the permanent effect manifests itself. Accordingly, there is a disadvantage in the second plan, in which the alcohol experiment proper is not preceded by a preliminary period with alcohol diet, in that the persistent effect of the alcohol may not become manifest during the first days of its use in the experiment. Whether, when, or how much this factor may influence a given experiment it is difficult to say.

On the other hand, there is a disadvantage in the first plan in that, as the experiments with and without alcohol are not consecutive, the body may, during the interval between them, become changed in its capacity or tendency to respond to the different diets. The second plan has the corresponding advantage that differences in the observed results in two consecutive periods might be more clearly due to the diet and less influenced by changes in bodily condition; but here, again, we are dealing with uncertainties.

To some it might seem that the best test of the effect of alcohol upon nitrogen metabolism would be found in experiments on the first plan, while others would consider those on the second plan more trustworthy. To the writers it seems that experiments on both plans are desirable. Of course the most desirable plan of all would be to continue the experiments through periods long enough to make sure that the normal action of the alcohol appears, and to alternate the alcohol periods with periods without alcohol. This plan has been followed successfully in experiments upon the special question of the protection of protein by alcohol, as explained in the discussion of this subject beyond.

GROUP A. EXPERIMENTS NOS. 9 AND 10. REST EXPERIMENTS WITH ORDINARY DIET AND WITH ALCOHOL DIET.

The 2 experiments in this group were planned to compare the effects of ordinary diet with those of alcohol diet when the subject did as little mental and muscular work as practicable. The subject, E. O., was the same as in a number of other experiments. The amounts of nutrients and energy per day in the diet in both experiments were such as previous observation and experiment with the same subject had indicated to be sufficient but not excessive. Experiment No. 10 was as exact a duplicate as possible of experiment No. 9, except that part of the fats and carbohydrates of the ordinary diet of No. 9 were taken out and were replaced in No. 10 by an amount of alcohol that was practically isodynamic with the fats and carbohydrates for which it was substituted, as explained below.

The preliminary digestion experiment preceding metabolism experiment No. 9 began with breakfast January 6, 1898, and continued 4 days. During this preliminary period the subject was engaged in his usual occupation as laboratory janitor, save that he had as little muscular exercise as practicable. His diet was essentially the same as during the period of actual experiment in the calorimeter.

The subject entered the respiration chamber on the evening of January 9, and experiment No. 9 began at 7 a. m. on January 10 and continued until 7 a. m. January 14. During this period within the chamber his occupation consisted of reading, writing, etc., but with very little muscular or mental activity. The diet furnished 120 grams of protein and 2,717 calories of energy per day.

Between the close of experiment No. 9 and the beginning of No. 10 there was an interval of about 4 weeks, in which the subject was engaged in his usual occupation as laboratory assistant. The preliminary digestion period of No. 10 began with breakfast February 11, 1898, and continued 4 days. The subject had as little muscular exercise as practicable aside from his regular occupation. The diet during the preliminary period was practically the same as during the experiment proper.

The subject entered the respiration chamber in the evening of February 14, and the experiment proper began at 7 a. m. February 15 and continued 4 days. The diet of the experiment, which furnished 123 grams of protein and 2,709 calories of energy per day, differed from the diet of experiment No. 9 in that about 37 grams of fat and 45 grams of carbohydrates, supplying 520 calories of energy, were taken out of the ordinary diet and were replaced by 80 grams of commercial alcohol with 90.6 per cent or 72.5 grams of absolute alcohol, having a heat of combustion of 512 calories. Thus, the amount of alcohol was very nearly isodynamic with the amounts of fats and carbohydrates which it replaced, and the total amounts of protein and energy were practically the same in the diets of both experiments.

The following table summarizes the results of these two experiments. Detailed data of the experiments will be found in Bulletin 69 of the Office of Experiment Stations of the United States Department of Agriculture.

TABLE 2.—*Summary of results of metabolism experiments Nos. 9 and 10.*

[Quantities per day.]

	Protein.	Fat.	Carbohydrates.	Alcohol.	Nitrogen.	Carbon.	Energy.
Experiment No. 9.	*Grams.*	*Grams.*	*Grams.*	*Grams.*	*Grams.*	*Grams.*	*Calories.*
In total food	119.6	69.0	341.8	....	19.1	261.6	2,717
In available food	111.7	64.9	329.7	....	17.8	235.6	2,426
Actually metabolized	115.3	46.7	(329.7)	....	18.4	223.6	2,277
Heat measured	....	....	....	....	....	....	2,309
Gain (+) or loss (−) to body	−3.6	+18.2	....	....	−0.6	+12.0	+149
Experiment No. 10.							
In total food	123.5	31.6	297.4	72.5	19.8	253.3	2,709
In available food	114.9	27.9	288.4	71.4	18.4	227.5	2,427
Actually metabolized	121.8	6.7	(288.4)	71.4	19.5	214.9	2,268
Heat measured	....	....	....	....	....	....	2,283
Gain (+) or loss (−) to body	−6.9	+21.2	....	....	−1.1	+12.6	+159

GROUP B. EXPERIMENTS NOS. 24 AND 22, WITH NO. 23 FOR COMPARISON. REST EXPERIMENTS WITH ORDINARY DIET AND WITH ALCOHOL.

The experiments of this group are a series of 3 carried out with E. O. in March, 1899. The purpose was to compare the effects of alcohol with those of sugar upon the metabolism of nitrogen and especially of carbon and energy, when the subject had little muscular or mental activity. During this series the subject remained in the calorimeter 9 days and 10 nights without intermission, and each experiment continued 3 days and nights. The plan of the experiments was to give the subject a diet consisting of a so-called basal ration which was the same in all 3 experiments, and a supplemental ration which was different in each experiment. The basal ration given was as large as the average of the rations that had been used in the previous experiments with the same subject. It furnished 123 grams of protein and 2,535 calories of energy per day. The supplemental ration consisted of alcohol in experiment No. 22 and sugar in experiment No. 24, each in quantity sufficient to furnish a little over 500 calories per day, as explained below. In experiment No. 23 the basal ration alone was given.

The preliminary digestion experiment continued 4 days, beginning with breakfast on March 9, the lampblack for the separation of the feces having been taken with the supper the night before. During this preliminary period the subject was engaged in his usual occupation as laboratory assistant, but had as little muscular exercise as practicable. For 3 days of this preliminary experiment the subject lived on the basal ration alone. On the fourth day 79.2 grams of commercial ethyl alcohol, with 90.9 per cent or 72 grams of absolute alcohol, were added to the diet. The alcohol was taken by the subject in coffee infusion, the total amount for the day being divided into 6 portions, one being taken at each meal and the other 3 portions between meals.

The subject entered the respiration chamber on the evening of March 12, and experiment No. 22 began at 7 o'clock in the morning of March 13 and continued until 7 a. m. March 16. During this experiment the diet consisted of the basal ration, supplemented each day by 72 grams of alcohol, as stated above. This amount of alcohol added 509 calories per day to the energy of the basal ration.

Experiment No. 23 began at 7 a. m. on March 16 and continued until 7 a. m. March 19. The diet in this experiment consisted of the basal ration alone without the alcohol, but at the request of the subject with the addition of a small amount of horseradish to add flavor to the diet.

Experiment No. 24 began at 7 a. m. March 19 and continued until 7 a. m. March 21. The diet in this experiment consisted of the basal ration and the horseradish, supplemented each day by 130 grams of cane sugar in the form of rock candy. The daily ration of candy was given to the subject each morning with breakfast, and he ate it as he felt disposed during the day. This amount of sugar added 515 calories per day to the energy of the basal ration, a similar amount to that added by the alcohol in experiment No. 22.

The following table summarizes the results of experiments Nos. 22 and 24. The results of No. 23 are also included, although they are not strictly comparable with either 22 or 24, because removal of the alcohol without replacement by any other material reduced the energy of the diet by about 500 calories. Detailed data of No. 22 will be found in the Appendix, pp. 330 to 342, and those of Nos. 23 and 24 will be found in Bulletin 109 of the Office of Experiment Stations.

TABLE 3.—*Summary of results of metabolism experiments Nos. 24, 22, and 23.*

[Quantities per day.]

	Protein.	Fat.	Carbohydrates.	Alcohol.	Nitrogen.	Carbon.	Energy.
Experiment No. 24.	*Grams.*	*Grams.*	*Grams.*	*Grams.*	*Grams.*	*Grams.*	*Calories.*
In total food	123.6	68.8	408.6	....	19.8	299.7	3,061
In available food	115.4	64.4	403.7	....	18.5	277.4	2,809
Actually metabolized	113.7	4.7	(403.7)	....	18.2	230.9	2,238
Heat measured	....	....	....	....	....	....	2,272
Gain (+) or loss (−) to body	+1.7	+59.7	....	....	+0.3	+46.5	+571
Experiment No. 23.							
In total food	123.6	68.8	278.6	....	19.8	244.9	2,546
In available food	116.6	65.1	272.6	....	18.7	234.6	2,432
Actually metabolized	118.2	56.2	(272.6)	....	19.0	228.5	2,216
Heat measured	....	....	....	....	....	....	2,176
Gain (+) or loss (−) to body	−1.6	+8.9	....	....	−0.3	+6.1	+75
Experiment No. 22.							
In total food	123.2	68.8	276.1	72.0	19.8	279.8	3,044
In available food	116.2	65.1	270.1	69.8	18.7	256.5	2,777
Actually metabolized	114.8	2.4	(270.1)	69.8	18.5	207.8	2,180
Heat measured	....	....	....	....	....	....	2,258
Gain (+) or loss (−) to body	+1.4	+62.7	....	....	+0.2	+48.7	+597

GROUP C. EXPERIMENTS NOS. 26, 28, AND 27. REST EXPERIMENTS WITH ORDINARY DIET AND WITH ALCOHOL DIET.

The series of experiments forming this group was carried out with J. F. S. in February, 1900. The purpose of the experiments was to obtain data concerning the relative power of isodynamic quantities of alcohol, sugar, and butter to replace one another in the diet, when the subject was at rest. During this series the subject remained in the calorimeter 9 days and 10 nights, and each experiment continued 3 days and nights. The diet consisted of a basal ration furnishing approximately 100 grams of protein and 1,982 calories of energy per day, which was uniform in all 3 experiments, and a supplemental ration which was differed in the several experiments, being butter in No. 26, alcohol in No. 27, and sugar in No. 28, the amount of each used being sufficient to furnish about 500 calories of energy.

The preliminary digestion experiment began with breakfast on February 10, and continued 4 days. During this preliminary period the diet consisted of the basal ration supplemented by 63.5 grams of butter, furnishing 0.1 of a gram of nitrogen and 508 calories of energy; thus making a total of 100 grams of protein and 2,490 calories of energy in the daily diet.

The subject entered the respiration chamber on the evening of February 13, and experiment No. 26 began at 7 a. m. February 14, and continued 3 days. During this experiment the diet consisted of the basal ration supplemented by fat in the form of butter, as in the preliminary digestion experiment.

Experiment No. 27 began at 7 a. m. February 17, and continued 3 days. During this experiment the diet consisted of the basal ration supplemented by 79.5 grams of commercial ethyl alcohol with 90.6 per cent or 72 grams of absolute alcohol supplying 509 calories of energy per day, so that during this experiment the daily diet furnished 99 grams of protein and 2,491 calories of energy. The alcohol was administered in sweetened water, and the mixture was consumed in 6 portions during the day, 3 with meals and 3 between meals.

Experiment No. 28 began at 7 a. m. February 20, and continued 3 days. The diet during this experiment consisted of the basal ration supplemented by 28 grams of sugar daily in the form of rock candy. The daily ration during this experiment thus furnished 99 grams of protein and 2,889 calories of energy. The total amount of rock candy for the day was supplied to the subject with his breakfast, and he ate it from time to time during the day according to his taste.

The major portion of it was consumed at about the hours at which the alcohol had been taken in the previous experiment.

The following table summarizes the results of these 3 experiments. Detailed data of experiment No. 27 will be found in the Appendix, pages 342 to 353, and those of experiments Nos. 26 and 28 in Bulletin 109 of the Office of Experiment Stations.

TABLE 4.—*Summary of results of metabolism experiments Nos. 26, 28, and 27.*

[Quantities per day.]

	Protein.	Fat.	Carbohydrates.	Alcohol.	Nitrogen.	Carbon.	Energy.
Experiment No. 26.	*Grams.*	*Grams.*	*Grams.*	*Grams.*	*Grams.*	*Grams.*	*Calories.*
In total food	99.6	94.8	247.2		15.9	233.2	2,490
In available food	92.7	92.0	240.5		14.8	212.8	2,256
Actually metabolized	96.2	67.6	(240.5)		15.4	196.1	2,043
Heat measured							2,085
Gain (+) or loss (−) to body	−3.5	+24.4			−0.6	+16.7	+213
Experiment No. 28.							
In total food	98.6	40.3	375.2		15.8	245.8	2,489
In available food	90.8	36.3	369.9		14.6	224.9	2,249
Actually metabolized	95.3	14.5	(369.9)		15.3	210.7	2,067
Heat measured							2,079
Gain (+) or loss (−) to body	−4.5	+21.8			−0.7	+14.2	+182
Average Nos. 26, 28.							
In total food	99.1	67.6	311.2		15.9	239.5	2,490
In available food	91.8	64.2	305.2		14.7	218.8	2,253
Actually metabolized	95.8	41.1	(305.2)		15.3	203.4	2,055
Heat measured							2,082
Gain (+) or loss (−) to body	−4.0	+23.1			−0.6	+15.4	+198
Experiment No. 27.							
In total food	98.6	40.3	247.2	72.0	15.8	229.5	2,491
In available food	91.6	38.2	240.1	71.1	14.7	208.9	2,264
Actually metabolized	97.6	20.0	(240.1)	71.1	15.7	198.3	2,125
Heat measured							2,123
Gain (+) or loss (−) to body	−6.0	+18.2			−1.0	+10.6	+139

GROUP D. EXPERIMENTS NOS. 11 AND 12. WORK EXPERIMENTS WITH ORDINARY DIET AND WITH ALCOHOL DIET.

The two experiments in this group were similar to those in Group A, except that those in Group A were rest experiments, while those in Group D were work experiments; that is, they were planned to compare the effects of ordinary diet and of alcohol diet when the subject was engaged in active muscular work. The subject, E. O., was the same in both groups. The work in these experiments was performed on the bicycle ergometer described on page 237.

The ordinary diet in experiment No. 11 furnished 124 grams of protein and 3,862 calories of energy per day. The amount of protein was nearly the same as in No. 9, but in order to supply energy for muscular work the amount of energy in No. 11 was made to exceed considerably that in No. 9 by an increase in the amount of fats and carbohydrates in the diet.

The preliminary period of this experiment began with breakfast, March 18, 1898, and continued 4 days. During this time the subject was engaged in his usual occupation, and took a considerable amount of exercise each day walking or riding a bicycle. On the evening of March 21 he entered the respiration chamber, and the experiment proper began at 7 a. m. March 22, and continued until 7 a. m. March 26.

Experiment No. 12 was intended to be as exact a duplicate as possible of experiment No. 11, except that some of the sugar, starch, and fat was taken out of the diet and replaced by an isodynamic amount of alcohol. The alcohol diet of this experiment furnished 121 grams of protein and 3,891 calories of energy per day, as compared with 124 grams of protein and 3,862 calories of energy per day in the ordinary diet of experiment No. 11. In consideration of the difficulties in planning and regulating the diet so as to furnish exactly a definite quantity of protein or energy, the agreement of the two diets in regard to amount of protein per day is very satisfactory.

In order to obtain a palatable diet in experiment No. 12, considerably more fat was furnished than in experiment No. 11, consequently the carbohydrates (sugars and starches) had to be reduced more than would be required for their replacement by the amount of alcohol used. The fat was increased by 30 grams, corresponding to about 285 calories of energy, and the carbohydrates were decreased by 189 grams, corresponding to about 770 calories. In the place of the materials left out of the diet 80 grams of commercial alcohol, with 90.5 per cent or 72.4 grams of pure ethyl alcohol, furnishing 512 calories of energy, were given each day. In this way the energy of the alcohol diet of experiment 12 was made to agree very satisfactorily with that of the ordinary diet of experiment No. 11.

The preliminary period of this experiment began with breakfast on April 8, 1898, and continued 4 days, during which the subject took considerable exercise in addition to his regular occupation. The diet during the preliminary period was the same as during the metabolism experiment proper. The subject entered the chamber on the evening of April 11; metabolism experiment No. 12 began at 7 a. m. April 12, and continued until 7 a. m. April 16.

The following table summarizes the results of these 2 experiments. Detailed data of experiment No. 12 will be found in the Appendix, pages 291 to 305; those of No. 11 in Bulletin 109 of the Office of Experiment Stations:

TABLE 5.—*Summary of results of metabolism experiments Nos. 11 and 12.*

[Quantities per day.]

	Protein.	Fat.	Carbohydrates.	Alcohol.	Nitrogen.	Carbon.	Energy.
Experiment No. 11.	*Grams.*	*Grams.*	*Grams.*	*Grams.*	*Grams.*	*Grams.*	*Calories.*
In total food	124.1	129.1	484.6	....	19.8	373.5	3,862
In available food	110.0	120.1	472.2	....	17.6	340.6	3,510
Actually metabolized	113.0	159.8	(472.2)	....	18.1	372.6	3,901
Heat measured	....	....	....	....	....	....	3,932
Gain (+) or loss (−) to body	−3.0	−39.7	....	....	−0.5	−32.0	−391
Experiment No. 12.							
In total food	120.6	158.5	296.1	72.4	19.3	344.8	3,891
In available food	112.8	152.0	290.4	70.9	18.0	319.6	3,614
Actually metabolized	113.8	184.2	(290.4)	70.9	18.2	344.7	3,922
Heat measured	....	....	....	....	....	....	3,927
Gain (+) loss (−) to body	−1.0	−32.2	....	....	−0.2	−25.1	−308

GROUP E. EXPERIMENTS NOS. 29, 31, AND 30. WORK EXPERIMENTS WITH ORDINARY DIET AND WITH ALCOHOL DIET.

The series of experiments forming this group was carried out in March, 1900. They were made with the same subject, J. F. S., as in Group C, and for the same purpose, namely, to study the relative replacing power of isodynamic quantities of alcohol, sugar, and fat. During this series the subject remained in the calorimeter 9 days and 10 nights without intermission, and each experiment in the series continued 3 days and nights. The experiments in Group E differ from those in Group C, however, in that the subject worked for 8 hours each day upon the bicycle ergometer, described on page 237. As in the previous series of experiments referred to, there was a basal ration which was the same and a supplemental ration which was different in each of the 3 experiments. The basal ration was planned to furnish approximately the same amount of protein as in the series in Group C, with the addition of about 1,000 calories of energy per day in order to furnish the extra energy required for the performance of the external muscular work and the general increase of bodily activity. It furnished about 100 grams of protein and from 2,949 to 2,984 calories of energy per day in the different experiments.

The preliminary digestion experiment began with breakfast March 12, 1900, and continued 4 days. The diet during this period consisted of the basal ration supplemented by cane sugar, as in experiment No. 29.

The subject entered the respiration chamber on the evening of March 15, and experiment No. 29 began at 7 a. m. March 16, and continued 3 days. During this experiment the diet consisted of the basal ration supplemented by 128 grams of cane sugar furnishing 507 calories of energy per day, as in the preliminary digestion period; the whole diet furnishing daily 100 grams of protein and 3,487 calories of energy. The daily amount of sugar in the form of rock candy was supplied to the subject each morning at breakfast, and he ate it at intervals during the day according to his taste.

Experiment No. 30 began at 7 a. m. March 19, immediately at the close of experiment 29. The diet in this experiment consisted of the basal ration supplemented by 79.5 grams of commercial alcohol containing 90.6 per cent or 72 grams of pure ethyl alcohol in place of the sugar of experiment No. 29. The alcohol supplied 509 calories of energy, and the whole ration in this experiment furnished 99 grams of protein and 3,458 calories of energy per day. The commercial alcohol used in this experiment was added each day to 795.5 grams of water sweetened with 25 grams of sugar from the basal ration. The total mixture, 900 grams, was divided into 6 portions which were taken with meals and between meals, as in other alcohol experiments.

Experiment No. 31 began at 7 a. m. on the morning of March 22, and continued 3 days. The diet in this experiment consisted of the basal ration supplemented by 63.5 grams of butter in place of the alcohol in the previous experiment. The butter furnished nearly 1 gram of protein and 511 calories of energy, so that the whole ration furnished 101 grams of protein and 3,495 calories of energy per day. The butter was consumed at meals with the rest of the diet.

The following table summarizes the results of these 3 experiments. Detailed data of experiment No. 30 will be found in the Appendix, pages 354 to 366, and those of experiments Nos. 29 and 31 will be found in Bulletin 109 of the Office of Experiment Stations.

TABLE 6.—*Summary of results of metabolism experiments Nos. 29, 31, and 30.*

[Quantities per day.]

	Protein.	Fat.	Carbohydrates.	Alcohol.	Nitrogen.	Carbon.	Energy.
Experiment No. 29.	*Grams.*	*Grams.*	*Grams.*	*Grams.*	*Grams.*	*Grams.*	*Calories.*
In total food	100.1	106.0	470.7	....	16.0	333.6	3,487
In available food	94.8	103.0	464.6	....	15.2	314.1	3,260
Actually metabolized	99.8	126.8	(464.6)	....	16.0	334.9	3,515
Heat measured	....	....	....	....	....	....	3,589
Gain (+) or loss (—) to body	—5.0	—23.8	....	....	—0.8	—20.8	—255
Experiment No. 31.							
In total food	100.9	160.8	342.7	....	16.1	321.5	3,495
In available food	95.8	158.1	336.7	....	15.3	302.5	3,275
Actually metabolized	98.1	174.0	(336.7)	....	15.6	315.8	3,439
Heat measured	....	....	....	....	....	....	3,420
Gain (+) or loss (—) to body	—2.3	—15.9	....	....	—0.3	—13.3	—164
Average 29 and 31.							
In total food	100.5	133.4	406.7	....	16.0	327.6	3,491
In available food	95.3	130.6	400.7	....	15.2	308.3	3,268
Actually metabolized	99.0	150.5	(400.7)	....	15.8	325.4	3,477
Heat measured	....	....	....	....	....	....	3,505
Gain (—) or loss (—) to body	—3.7	—19.9	....	....	—0.6	—17.1	—209
Experiment No. 30.							
In total food	99.2	104.2	340.9	72.0	15.9	315.5	3,458
In available food	94.9	102.1	336.2	71.2	15.2	296.6	3,242
Actually metabolized	108.0	119.1	(336.2)	71.2	17.3	316.5	3,479
Heat measured	....	....	....	....	....	....	3,470
Gain (+) or loss (—) to body	—13.1	—17.0	....	....	—2.1	—19.9	—237

GROUP F. EXPERIMENTS NOS. 32, 34, AND 33. WORK EXPERIMENTS WITH ORDINARY AND WITH ALCOHOL DIET.

The series of experiments forming this group was made in April, 1900. The plan of the experiments in this series was as nearly as possible a duplicate of that of the experiments forming Group E, the chief difference being that in the series in Group E the basal ration was supplemented in the first experiment by sugar, in the second by alcohol, and in the third by butter, whereas in the series in Group F the butter was used in the first experiment, alcohol in the second, and sugar in the third. Both series were work experiments in which the same subject, J. F. S., spent 8 hours each day working on the bicycle ergometer. In each series the subject remained 9 successive days within the calorimeter, and the whole investigation was divided into 3 experiments of 3 days each, the different experiments being distinguished from each other by changes in the supplemental ration. The basal ration in this series furnished 100 grams of protein and about 2,977 calories of energy per day. The amount of energy in the basal ration varied slightly in the successive experiments of the series, because of slight differences in the composition of the milk.

The preliminary digestion experiment began with breakfast April 16 and continued 4 days. The diet consisted of the basal ration supplemented with fat in the form of butter, as in experiment No. 32.

The subject entered the respiration chamber on the evening of April 19 and experiment No. 32 began at 7 a. m. April 20 and continued 3 days. The diet consisted of the basal ration supplemented by 63.5 grams of butter, furnishing 1 gram of protein and 510 calories of energy. The butter was consumed at meals with the rest of the diet. The total diet in this experiment supplied 101 grams of protein and 3,487 calories of energy per day.

Experiment No. 33 began at 7 a. m. April 23 and continued 3 days. The diet in this experiment consisted of the basal ration, supplemented by 79.5 grams of commercial alcohol with 90.6 per cent, or 72 grams, of absolute alcohol, furnishing 509 calories of energy. The commercial alcohol was added each day to 795.5 grams of water sweetened with 25 grams of sugar, making 900 grams of a mixture which was divided into six portions (see p. 292), the larger of which were taken at meals and the smaller between meals and before retiring. The total diet in this experiment furnished 100 grams of protein and 3,486 calories of energy per day.

Experiment No. 34 began at 7 a. m. April 26 and continued 3 days. The diet consisted of the basal ration supplemented by 128 grams of cane sugar, furnishing 507 calories of energy. The daily amount of sugar was supplied to the subject each morning in the form of rock candy, which he ate at intervals during the day according to his taste. The total diet in this experiment furnished 100 grams of protein and 3,493 calories of energy per day.

The following table summarizes the results of these 3 experiments. Detailed data of experiment No. 33 will be found in the Appendix, pages 366 to 378, and those of experiments Nos. 32 and 34 in Bulletin 109 of the Office of Experiment Stations:

TABLE 7.—*Summary of results of metabolism experiments Nos. 32, 34, and 33.*

[Quantities per day.]

	Protein.	Fat.	Carbohydrates.	Alcohol.	Nitrogen.	Carbon.	Energy.
Experiment No. 32.	*Grams.*	*Grams.*	*Grams.*	*Grams.*	*Grams.*	*Grams.*	*Calories.*
In total food	100.5	151.6	353.9	....	16.1	320.0	3,487
In available food	93.1	147.2	344.5	....	14.9	296.4	3,226
Actually metabolized	98.1	182.1	(344.5)	....	15.7	325.6	3,573
Heat measured	....	....	....	....	....	....	3,565
Gain (+) or loss (−) to body	−5.0	−34.9	....	....	−0.8	−29.2	−347
Experiment No. 34.							
In total food	99.7	99.3	477.9	....	16.0	335.7	3,493
In available food	92.4	94.4	470.1	....	14.8	312.5	3,241
Actually metabolized	104.3	129.4	(470.1)	....	16.7	345.4	3,629
Heat measured	....	....	....	....	....	....	3,587
Gain (+) or loss (−) to body	−11.9	−35.0	....	....	−1.9	−32.9	−388

TABLE 7.—*Summary of results of metabolism experiments Nos. 32, 34, and 33*—Continued.

	Protein.	Fat.	Carbohydrates.	Alcohol.	Nitrogen.	Carbon.	Energy.
Average Nos. 32 and 34.	*Grams.*	*Grams.*	*Grams.*	*Grams.*	*Grams.*	*Grams.*	*Calories.*
In total food	100.1	125.5	415.9		16.0	327.8	3,490
In available food	92.8	120.8	407.3		14.8	304.4	3,234
Actually metabolized	101.3	155.8	(407.3)		16.2	335.5	3,601
Heat measured							3,576
Gain (+) or loss (−) to body	−8.5	−35.0			−1.4	−31.1	−367
Experiment No. 33.							
In total food	99.7	99.3	355.0	72.0	16.0	319.6	3,486
In available food	92.4	95.0	346.9	71.3	14.8	295.7	3,227
Actually metabolized	108.2	133.4	(346.9)	71.3	17.3	333.3	3,669
Heat measured							3,632
Gain (+) or loss (−) to body	−15.8	−38.4			−2.5	−37.6	−442

GROUP G. EXPERIMENTS NOS. 13, 14, AND 7. REST EXPERIMENTS WITH ORDINARY AND WITH ALCOHOL DIET.

While the 3 experiments in this group are all rest experiments and all with the same subject, E. O., the ordinary experiments and the alcohol experiments were not planned to be exact duplicates of each other, and are therefore less exactly comparable than those in preceding groups. For the sake of comparison with the alcohol experiment, No. 7, however, 2 ordinary experiments, Nos. 13 and 14, were chosen in which the average of the amounts of protein and energy in the daily diet in the 2 experiments was practically the same as in the alcohol experiment. Since these experiments were made with the same subject and under conditions somewhat similar, the results may be compared in studying the effect of alcohol on metabolism.

Experiment No. 13 was intended to be as nearly as possible a duplicate of experiment No. 9. The ordinary diet in experiment No. 13 furnished 117 grams of protein and 2,596 calories of energy per day, which was 2 grams of protein and 121 calories of energy less than in No. 9. The preliminary period of No. 13 began with breakfast November 8, 1898, and continued 4 days, during which the subject had as little muscular exercise as practicable outside of his regular occupation as laboratory assistant. He entered the chamber on the evening of November 7, and the experiment proper began at 7 a. m. November 8. It was intended that the experiment should continue 4 days, but on the fourth day a leak occurred in the ventilating air pipe at such a point that the results for that day were destroyed; consequently the experiment is recorded as a 3-day experiment. While this was a rest experiment in general character, the subject was not so quiet throughout the experimental period as he had been in earlier and was in later similar experiments.

Experiment No. 14 was carried out under much the same conditions as No. 13, with the exception that in No. 14 the amount of protein in the diet was reduced from 117 to 94 grams per day, and the energy from 2,596 to 2,513 calories per day. The preliminary digestion experiment began with breakfast December 17, 1898, and continued 3 days. The subject entered the apparatus on the evening of December 19, and the experiment proper began at 7. a. m. December 20 and continued 4 days.

The average of the amounts of protein and energy in the daily diet of the 2 ordinary experiments, 13 and 14, was 105 grams of protein and 2,555 calories of energy.

The alcohol diet in experiment No. 7 furnished 104 grams of protein and 2,462 calories of energy per day. The diet in this experiment included 80 grams of commercial alcohol, with 90.6 per cent, or 72.5 grams, of pure ethyl alcohol, which furnished 512 calories of energy per day. The preliminary digestion experiment began with breakfast June 4, 1897, and continued 4 days. The subject entered the chamber on the evening of June 7, and the experiment proper began at 7 p. m. June 8 and continued 4 days.

The following table summarizes the results of these experiments. Detailed data of experiment No. 7 will be found in Bulletin 69, and those of Nos. 13 and 14 in Bulletin 109 of the Office of Experiment Stations:

TABLE 8.—*Summary of results of metabolism experiments Nos. 13, 14, and 7.*

[Quantities per day.]

	Protein.	Fat.	Carbohydrates.	Alcohol.	Nitrogen.	Carbon.	Energy.
Experiment No. 13.	*Grams.*	*Grams.*	*Grams.*	*Grams.*	*Grams.*	*Grams.*	*Calories.*
In total food	117.1	87.8	270.2	....	18.7	245.8	2,596
In available food	110.2	81.6	265.0	....	17.6	219.6	2,298
Actually metabolized	121.9	54.7	(265.0)	....	19.5	205.2	2,112
Heat measured	....	....	....	....	....	....	2,151
Gain (+) or loss (−) to body	−11.7	+26.9	....	....	−1.9	+14.4	+186
Experiment No. 14.							
In total food	94.4	82.5	289.8	....	15.1	239.0	2,513
In available food	89.0	78.8	286.6	....	14.2	219.4	2,289
Actually metabolized	101.4	54.4	(286.6)	....	16.2	207.3	2,131
Heat measured	....	....	....	....	....	....	2,193
Gain (+) or loss (−) to body	−12.4	+24.4	....	....	−2.0	+12.1	+158
Average, experiments Nos. 13–14.							
In total food	105.8	85.2	280.0	....	16.9	242.4	2,555
In available food	99.6	80.2	275.8	....	15.9	219.5	2,294
Actually metabolized	111.7	54.5	(275.8)	....	17.8	206.3	2,122
Heat measured	....	....	....	....	....	....	2,172
Gain (+) or loss (−) to body	−12.0	+25.7	....	....	−1.9	+13.2	+172
Experiment No. 7.							
In total food	104.4	68.2	190.4	72.5	16.7	218.6	2,462
In available food	98.8	65.8	186.6	69.5	15.8	197.1	2,230
Actually metabolized	110.8	80.1	(186.6)	69.5	17.7	214.5	2,434
Heat measured	....	....	....	....	....	....	2,394
Gain (+) or loss (−) to body	−12.0	−14.3	....	....	−1.9	−17.4	−204

GROUP H. EXPERIMENTS NOS. 5, 15–17. REST EXPERIMENTS WITH ORDINARY DIET AND WITH ALCOHOL DIET.

The experiments in Group H were all rest experiments with the same subject, E. O. One purpose of the 3 experiments with alcohol diet (Nos. 15–17) was to compare the effect of alcohol when taken in different forms, as commercial alcohol, whisky, or brandy. The experiment with ordinary diet (No. 5) has been chosen for comparison with the 3 experiments with alcohol diet for the reason that, while the amount of protein was somewhat larger in the former than in the latter, the amount of energy was practically the same in both diets. The experiments in this group are less comparable than those in Groups G and I because of differences in the circumstances under which the experiments were made. Experiment No. 5 was the first of the series of metabolism experiments in which the determinations of income and outgo of both matter and energy were made. The diet in this experiment was more varied than that in some of the later experiments, and the methods of sampling were not satisfactory, which will account in part for the unusually wide discrepancies between the theoretical values for income and those actually found for outgo of energy. On the other hand, experiments Nos. 15–17 were made at a later period when the apparatus and the methods of experimenting were much improved.

The preliminary period of experiment No. 5 began April 27, 1897, and continued 8 days, instead of 4 days as usual, because unexpected circumstances delayed the starting of the experiment proper. The subject entered the calorimeter at about 9 o'clock on the evening of May 3 and the experiment proper began at 7 a. m. May 4, and continued 4 days. The diet in this experiment furnished 119 grams of protein and 2,655 calories of energy per day.

Each of the 3 experiments, Nos. 15–17, was of 2 days' duration, and one followed the other without intermission and without the subject leaving the respiration chamber, so that in a way they constitute one long experiment. No attempt was made to obtain a separation of the feces for the different experiments. The usual separations, however, were made, the first between the preliminary digestion experiment and the beginning of metabolism experiment No. 15, and the second at the close of experiment No. 17. The diet in these experiments consisted of a basal ration which was the same in all 3 experiments, supplemented by alcohol in the form of pure ethyl alcohol in experiment No. 15, by alcohol in the form of whisky in experiment No. 16, and by alcohol in the form of brandy in experiment No. 17. The total diet including the alcohol furnished 109 grams of protein and 2,653 calories of energy per day.

The preliminary digestion experiment began January 12, 1899, and continued 4 days as usual. During this preliminary experiment the subject received the basal ration, and in addition to this 72.5 grams of absolute ethyl alcohol, which was administered daily in coffee infusion sweetened with 45 grams of sugar.

The subject entered the respiration chamber on the evening of January 15 and experiment 15 began at 7 a. m. January 16. During this experiment he received the basal ration supplemented by 79.8 grams of 90.9 per cent commercial alcohol, or 72.5 grams of absolute ethyl alcohol, in 775.2 grams of coffee infusion, the whole of which was sweetened with 45 grams of cane sugar. There was 900 grams of the mixture which sufficed for the whole day. This was taken at 6 intervals, the larger portions being consumed with the meals and the smaller portions between meals and just before retiring.

Experiment No. 16 began at 7 a. m. January 18, and continued 2 days. The diet in this experiment consisted of the basal ration supplemented by 158.3 grams of whisky, with 45.8 per cent, or 72.5 grams, of absolute alcohol. This was mixed with 696.7 grams of water sweetened with 54 grams of sugar, and the whole divided into 6 doses and taken as before. The mixture was made with water rather than with coffee infusion, because it was thought the objection might be raised that the coffee might perhaps, to some extent, counteract the effect of the alcohol. The whisky, sugar, and water were furnished to the subject, who mixed them at the usual hours within the apparatus. The amount of alcohol found in the air current was larger during this experiment than during the one preceding it, suggesting that some alcohol may have been volatilized as the whisky was poured into the drinking cup and mixed with the water. The mixing was therefore done outside the apparatus in the next experiment, and the alcohol in the air current was again less than in No. 16.

Experiment No. 17 began at 7 a. m. January 20, and continued 2 days, during which the subject received the basal ration supplemented by 143.8 grams of brandy, with 50.4 per cent, or 72.5 grams, of absolute alcohol, per day. This amount was added to 711.2 grams of water and 45 grams of sugar, making a total of 900 grams of the mixture, which was administered in 6 portions, as in the previous experiments.

The following table summarizes the results of these 4 experiments. Detailed data of experiments Nos. 15–17 will be found in the Appendix, pages 305 to 317; those of No. 5 will be found in Bulletin 69 of the Office of Experiment Stations:

TABLE 9.—*Summary of results of metabolism experiments Nos. 5 and 15–17.*

[Quantities per day.]

	Protein.	Fat.	Carbohydrates.	Alcohol.	Nitrogen.	Carbon.	Energy.
Experiment No. 5.	*Grams.*	*Grams.*	*Grams.*	*Grams.*	*Grams.*	*Grams.*	*Calories.*
In total food	119.1	94.7	275.5	....	19.1	248.9	2,655
In available food	108.8	89.0	269.1	....	17.4	223.5	2,384
Actually metabolized	113.0	96.8	(269.1)	....	18.1	231.7	2,482
Heat measured							2,379
Gain (+) or loss (−) to body	−4.2	−7.8			−0.7	−8.2	−98
Experiment No. 15.							
In total food	108.9	39.9	276.9	72.5	17.4	245.7	2,653
In available food	103.8	36.9	272.4	71.0	16.6	226.1	2,426
Actually metabolized	97.8	33.1	(272.4)	71.0	15.6	220.0	2,357
Heat measured							2,362
Gain (+) or loss (−) to body	+6.0	−3.8			+1.0	+6.1	+69

TABLE 9.—*Summary of results of metabolism experiments Nos. 5 and 15–17*—Continued.

[Quantities per day.]

	Protein.	Fat.	Carbohydrates.	Alcohol.	Nitrogen.	Carbon.	Energy.
Experiment No. 16.	*Grams.*	*Grams.*	*Grams.*	*Grams.*	*Grams.*	*Grams.*	*Calories.*
In total food	108.9	39.9	276.9	72.5	17.4	245.7	2,653
In available food	103.8	36.9	272.4	70.4	16.6	225.9	2,424
Actually metabolized	96.6	31.9	(272.4)	70.4	15.5	218.3	2,336
Heat measured	....	....	....	....	....	....	2,332
Gain (+) or loss (−) to body	+7.2	+5.0	....	....	+1.1	+7.6	+88
Experiment No. 17.							
In total food	108.9	39.9	276.9	72.5	17.4	245.7	2,653
In available food	103.8	36.9	272.4	71.0	16.6	226.1	2,427
Actually metabolized	97.8	25.9	(272.4)	71.0	15.6	214.5	2,289
Heat measured	....	....	....	....	....	....	2,276
Gain (+) or loss (−) to body	+6.0	+11.0	....	....	+1.0	+11.6	+138
Average, Nos. 15, 16, and 17.							
In total food	108.9	39.9	276.9	72.5	17.4	245.7	2,653
In available food	103.8	36.9	272.4	70.8	16.6	226.0	2,426
Actually metabolized	97.4	30.3	(272.4)	70.8	15.6	217.6	2,327
Heat measured	....	....	....	....	....	....	2,323
Gain (+) or loss (−) to body	+6.4	+6.6	....	....	+1.0	+8.4	−99

GROUP 1. EXPERIMENTS NOS. 21 AND 18–20. REST EXPERIMENTS WITH ORDINARY AND WITH ALCOHOL DIET.

The series of experiments comprising this group was carried out in February, 1899. The purpose of the experiments with alcohol diet in this series was the same as that of experiments 15–17, namely, to determine whether there is any difference in the effect of alcohol when taken in different forms. Experiments Nos. 18–20 were somewhat similar in plan to Nos. 15–17, but were made with a different subject, A. W. S. The subject remained in the calorimeter 9 days without intermission. During the first 6 days of this period the 3 alcohol experiments, Nos. 18–20, were made, each of 2 days' duration, as in experiments 15–17. These were followed by one experiment, No. 21, of 3 days, in which the diet contained no alcohol.

As in the preceding series, the diet in experiments 18–21 consisted of a basal ration which was the same in all the experiments, and a supplemental ration which was different in each. This basal ration furnished 97 grams of protein and 2,264 calories of energy per day. In experiments Nos. 18–20 the basal ration was supplemented by commercial alcohol, whisky, and brandy, respectively, the quantity of each used being sufficient to furnish 72.5 grams of absolute alcohol per day, with a heat of combustion of 512 calories. The total diet in the alcohol experiments furnished 97 grams of protein and 2,776 calories of energy per day. In experiment No. 21 the alcohol was omitted, and the diet consisted of the basal ration alone.

The preliminary digestion experiment began with breakfast February 2, and continued 4 days. During this period the diet was the same as in experiment No. 18, and consisted of the basal ration and the alcohol in the form of commercial spirits, which was administered in coffee infusion, sweetened with sugar.

The subject entered the respiration chamber on the evening of February 5, and experiment No. 18 began at 7 a. m. February 6, and continued 2 days. In this experiment the diet consisted of the basal ration, supplemented by 79.8 grams of commercial alcohol, with 90.9 per cent, or 72.5 grams, of absolute alcohol. The commercial spirits was mixed with 775.2 grams of coffee infusion, sweetened with 45 grams of cane sugar. The whole mixture made 900 grams, which was divided into 6 portions, the larger of which were taken with meals, and the smaller between meals and just before retiring.

Experiment No. 19 began at 7 a. m. February 8, and continued 2 days. The diet in this experiment consisted of the basal ration, supplemented by 158.3 grams of whisky, with 45.8 per cent, or 72.5 grams, of absolute alcohol. The whisky was mixed with 696.7 grams of water, sweetened with 45 grams of cane sugar, the whole mixture forming 900 grams, which was administered as in experiment No. 18.

Experiment No. 20 began at 7 a. m. February 10, and continued 2 days, during which the diet consisted of the basal ration, supplemented by 143.8 grams of brandy, with 50.4 per cent, or 72.5 grams, of absolute alcohol. The brandy was mixed with 711.2 grams of water, sweetened with 45 grams of cane sugar. The whole mixture amounted to 900 grams, which was administered in 6 portions as in the previous experiments.

Experiment No. 21 began at 7 a. m. February 12, and continued 3 days. The diet in this experiment consisted of the basal ration alone, without alcohol. The results of this experiment are here given in comparison with 3 alcohol experiments because it was a part of the same series and followed the alcohol experiments without intermission and without the subject leaving the respiration chamber. The results are hardly comparable with those of the alcohol experiments, however, since by the omission of the alcohol from the diet the amount of energy per day was reduced nearly one-fifth, while the amounts of protein, fats, and carbohydrates remained the same.

The following table summarizes the results of these 4 experiments. Detailed data of experiments Nos. 18–20 may be found on pages 317 to 330 in the Appendix. Those of No. 21 may be found in Bulletin 109 of the Office of Experiment Stations.

TABLE 10.—*Summary of results of metabolism experiments Nos. 18, 19, and 20.*

[Quantities per day.]

	Protein.	Fat.	Carbohydrates.	Alcohol.	Nitrogen.	Carbon.	Energy.
Experiment No. 21.	*Grams.*	*Grams.*	*Grams.*	*Grams.*	*Grams.*	*Grams.*	*Calories.*
In total food	96.9	72.4	250.1	....	15.5	215.2	2,264
In available food	90.4	68.4	246.1	....	14.5	195.4	2,038
Actually metabolized	96.0	93.3	(246.1)	....	15.4	217.4	2,304
Heat measured	....	....	....	....	....	....	2,279
Gain (+) or loss (−) to body	−5.6	−24.9	....	....	−0.9	−22.0	−266
Experiment No. 18.							
In total food	96.9	72.4	250.1	72.5	15.5	253.0	2,776
In available food	90.4	68.4	246.1	69.5	14.4	232.0	2,532
Actually metabolized	102.6	43.3	(246.1)	69.5	16.4	219.3	2,367
Heat measured	....	....	....	....	....	....	2,485
Gain (+) or loss (−) to body	−12.2	+25.1	....	....	−2.0	+12.7	+168
Experiment No. 19.							
In total food	96.9	72.4	250.1	72.5	15.5	253.0	2,776
In available food	90.4	68.4	246.1	69.9	14.5	233.5	2,550
Actually metabolized	90.4	33.3	(246.1)	69.9	14.5	206.6	2,220
Heat measured	....	....	....	....	....	....	2,279
Gain (+) or loss (−) to body	....	+35.1	....	....	....	+26.9	+330
Experiment No. 20.							
In total food	96.9	72.4	250.1	72.5	15.5	253.0	2,776
In available food	90.4	68.4	246.1	69.7	14.5	233.5	2,549
Actually metabolized	88.2	47.3	(246.1)	69.7	14.1	216.2	2,339
Heat measured	....	....	....	....	....	....	2,303
Gain (+) or loss (−) to body	+2.2	+21.1	....	....	+0.4	+17.3	+210
Average of 18, 19, and 20.							
In total food	96.9	72.4	250.1	72.5	15.5	253.0	2,776
In available food	90.4	68.4	246.1	69.7	14.5	233.0	2,544
Actually metabolized	93.7	41.3	(246.1)	69.7	15.0	214.1	2,308
Heat measured	....	....	....	....	....	....	2,357
Gain (+) or loss (−) to body	−3.3	+27.1	....	....	−0.5	+18.9	+236

DIGESTION EXPERIMENTS.

The data of the metabolism experiments above described include statistics of the amounts of nutrients consumed in the food and excreted in the feces. The difference between these amounts represents the so-called digestible or available nutrients.[a] The amount of each nutrient thus made available divided by the amount in the corresponding food is here taken as the coefficient of availability.

Each metabolism experiment, therefore, includes a digestion experiment; furthermore, each metabolism experiment or series of experiments was preceded by a digestion experiment, generally of 4 days' duration, during which the subject was outside the respiration calorimeter, but had the same diet, and as nearly as convenient the same amount of muscular exercise, as in the metabolism experiment. We thus have for each metabolism experiment or series of metabolism experiments two corresponding digestion experiments. While the chief object of the preliminary experiment was to bring the body into approximate nitrogen equilibrium, the results, as bearing upon the availability of the food, are of importance.

The portions of protein, fat, carbohydrates, and ash not made available are eliminated in the feces. The unavailable alcohol is eliminated through the kidneys, lungs, and skin, and was determined in these experiments according to the method described beyond (p. 258).

In what has been said about the availability of the different nutrients in food no reference has been made to the availability of the energy. While it is commonly believed that all of the energy of the available fats and carbohydrates is capable of use by the body, all of the energy of the protein can not be so utilized. The nitrogen of the available protein is eliminated from the body in the form of urea, uric acid, and similar compounds, carrying with them a certain amount of energy. From the results of a considerable number of determinations of the ratio of the heat of combustion of urine to the available protein it has been found that for each gram of the latter there is lost in the urine an average of 1.25 calories of energy. This amount must therefore be deducted from the energy of the available food in order to obtain the available energy of the available protein. This is done by multiplying the number of grams of the latter by 1.25, and deducting the product from the difference between the total energy in the food and that in the feces. The difference gives the amount of available energy, which, divided by the total energy in the food consumed, gives the coefficient of availability of the energy.[b]

The proportions of the different nutrients digested and made available in any given case depend upon the diet and the individual. So far as concerns the diet, the availability may vary with (1) the kinds, (2) the amounts of food materials, (3) the method of preparation, and (4) the accessories, including condiments, beverages, etc., and with the rest, alcoholic beverages. The same diet may be differently digested by different individuals or by the same individual under different conditions of health, physical activity, and nervous strain.

The details of the digestion experiments with alcohol diet are given in Tables CV to CXVIII of the Appendix.

Table 11 compares the availability of food in diets with and without alcohol and the availability of the same diet with the same persons outside and inside the respiration chamber. In the first case the principal difference is that of diet, the alcohol being the chief factor; in the second case the differences are those of the physical and mental condition of the individual. The discussion of the effect of alcohol upon availability of the nutrients of the diet is given on pages 256 to 258, beyond.

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[a] For further discussion see page 256 beyond, and Repts. Storrs (Conn.) Agr. Exp. Sta., 1896, p. 163, and 1897, p. 154.

[b] For further discussion of this subject see ATWATER and BRYANT, Rept. Storrs (Conn.) Agr. Exp. Sta., 1899, p. 96. See also discussion by W. O. ATWATER in Bul. 99 of the U. S. Dept. Agr., Office of Experiment Stations, Proceedings of the Association of American Agricultural Colleges and Experiment Stations, 1900, p. 112.

TABLE 11.—*Summary of coefficients of availability of nutrients and energy in preliminary and calorimeter periods and with ordinary and alcohol diet.*

	Protein.	Fat.	Carbohydrates.	Energy.
Experiments with E. O.	*Per cent.*	*Per cent.*	*Per cent.*	*Per cent.*
Ordinary diet, average 6 experiments	92.4	93.8	97.9	90.6
Alcohol diet, average 5 experiments	94.2	93.5	97.9	91.1
Preliminary period, average 12 experiments	92.5	93.7	97.7	90.7
Calorimeter period, average 12 experiments	93.2	94.1	97.9	90.9
Experiments with J. F. S.				
Ordinary diet, average 6 experiments	93.4	95.8	98.1	92.7
Alcohol diet, average 3 experiments	93.8	96.2	97.9	93.0
Preliminary period, average 4 experiments	92.1	95.8	97.2	91.4
Calorimeter period, average 4 experiments	93.8	97.2	97.7	92.4
Average 12 experiments with ordinary food	92.9	94.7	98.0	91.7
Average 8 experiments with alcohol	94.0	94.5	97.9	91.8
Average 16 preliminary periods	92.4	94.2	97.6	90.9
Average 16 calorimeter periods	93.3	94.9	97.8	91.3

DISCUSSION OF THE RESULTS OF THE EXPERIMENTS.

The special purpose of the experiments summarized on the preceding pages, in so far as they have had to do with the nutritive action of alcohol, has been the study of the metabolism of the energy of alcohol and its consequent value for fuel as compared with isodynamic amounts of carbohydrates and fats. Incidentally, its effects upon digestion, the completeness of its oxidation, and its action in protecting body fat and protein from oxidation have also been observed. The more important results may be discussed under the following topics:

1. Effect of alcohol upon the digestion of food.
2. Proportions of alcohol oxidized and unoxidized.
3. Metabolism of the energy of alcohol.
4. Protection of body material by alcohol.
    a, Protection of body fat.
    b, Protection of body protein.
5. Effect of alcohol upon the radiation of heat from the body.
6. Alcohol as a source of heat in the body.
7. Alcohol as a source of muscular energy.

EFFECT OF ALCOHOL UPON THE DIGESTION OF FOOD.—DIGESTIBILITY VERSUS AVAILABILITY OF NUTRIENTS.

The term digestibility as applied to food has several meanings, which are not clearly distinguished in popular usage. It commonly refers to either the ease with which a given food material is digested, or the time required for the process, or the extent to which the material "agrees" or "disagrees" with different persons, or its effects upon bodily comfort and health. These factors depend largely upon individual peculiarities, vary widely with different persons and with the character of the food, and are difficult to measure.

The term digestibility is also used to designate the quantity or proportion of the food or of each of its different ingredients—protein, fats, carbohydrates, and mineral matters—actually digested and absorbed in the passage of the food through the digestive tract. Only this latter factor of digestibility is considered in these experiments. To determine what amount of each nutrient is actually digested it is necessary to know the quantity that is taken into the body in food and the quantity that has escaped digestion and is excreted in the feces. The latter quantity is not easily determined, however, because the feces contain, besides those portions of the food that have resisted the action of the digestive juices, other materials, the so-called metabolic products, which are mainly the residues of the digestive juices, and which are not easily separated from the undigested portion of the food. For this reason it is difficult to determine the actual digestibility of food or of its several ingredients.

The availability of the food or of the several ingredients, however, may be more accurately determined. By availability is here meant the quantity or proportion that can be used for the building and repair of tissue and the yielding of energy. The metabolic products, although derived originally from the digested food, are not used for either building material or fuel, and hence are not available in the sense in which the word is here employed. They may, therefore, be included with the undigested residue of the food and the small quantities of intestinal epithelium and other materials which make up the rest of the feces, and the amounts of available nutrients may be found by subtracting from the total ingredients of the food the total corresponding ingredients in the feces. These have often been called the digestible rather than the available nutrients, but the distinction here made is quite important.

The availability of the ingredients as thus determined is usually expressed by the percentage of the total amount of each in the food. This percentage is called the coefficient of availability. In the following table, which is a summary of a more detailed table given in the Appendix, the coefficients of availability of the protein, fats, and carbohydrates of the ordinary diet are compared with those of the alcohol diet, as actually found in the experiments. The average coefficients of availability of the nutrients of food as found in 93 experiments[a] with healthy men with ordinary diet under various conditions of work and rest are appended in the table for comparison.

TABLE 12.—*Coefficients of availability of food in the averages of experiments with and without alcohol.*

Kind and number of experiments.	Coefficients of availability.			
	Protein.	Fat.	Carbohydrates.	Energy.
Experiments more directly comparable.				
	Per cent.	*Per cent.*	*Per cent.*	*Per cent.*
Without alcohol, Nos. 9, 11, 26 and 28, 29 and 31, 32 and 34	92.6	94.9	97.9	91.8
With alcohol, Nos. 10, 12, 27, 31, 33	93.7	94.6	97.8	92.1
Experiments less directly comparable.				
Without alcohol, Nos. 5, and 13 and 14	92.6	94.1	98.1	90.3
With alcohol, Nos. 7 and 15 to 17	95.0	94.4	97.3	91.3
Average of other observations	93.0	95.0	98.0	[a] 92.3

[a] Availability of energy based upon average proportions and amounts of nutrients found in dietaries of 38 families of farmers, mechanics, and professional men and 15 college boarding clubs in different parts of the United States. See article by A. P. BRYANT on "Some Results of Dietary Studies." Yearbook U. S. Dept. Agriculture, 1898, p. 439.

It thus appears that the alcohol had little appreciable effect upon the availability of the other ingredients of the diet: the coefficients of availability of the nutrients of the ordinary food were practically the same with and without alcohol as part of the diet. The protein appears to have been slightly more available when the diet contained alcohol. The differences, especially in the more comparable experiments, are less than might be found with different subjects using the same ordinary food, or with the same subject using the same food at different times and under different conditions.

The conclusion from the results of these experiments would be to the effect that alcohol in moderate amounts tended to increase very slightly the availability of the nutrients of the diet, especially of the protein. In view, however, of the fact that there are often marked differences in the availability of the same diet with different persons and with the same person at different

[a] See ATWATER and BRYANT, Availability and Fuel Value of Food Materials, Rept. Storrs (Conn.) Expt. Sta., 1899, p. 73.

times, even this conclusion should be held with a degree of reserve. While it is statistically valid for these experiments, the extent to which it would be true in general experience is by no means certain.

PROPORTIONS OF ALCOHOL OXIDIZED AND UNOXIDIZED.

The difference between the amount of alcohol taken into the body in food and the amount given off unoxidized by the kidneys, lungs, and skin is taken as the amount oxidized in the body. For the determination of the amounts not oxidized in the body quantitative examination was made of the several excretory products for the presence of alcohol. No similar examination of the feces for alcohol was practicable; but, as it has been found in other experiments[a] that no alcohol was excreted through this channel, even when considerable quantities were ingested, it was here assumed that the feces would contain no appreciable amount of the alcohol taken with the food.

The alcohol eliminated by the kidneys would, of course, be found in the urine; that given off by the lungs and skin in the "drip" water collected from the surface of the system of cooling tubes, or it might pass out of the chamber as vapor in the air current and be condensed in the "freezers," in which a large part of the water is collected from the outgoing air, or it might even pass through the freezers as vapor and be ultimately absorbed in concentrated sulphuric acid in an apparatus arranged for the purpose.

The determinations of the amounts of alcohol given off from the body unoxidized in experiment No. 7 were made according to the method described by Bodländer.[b] This method, however, does not give results sufficiently accurate when the amounts of alcohol are as small as were found in these experiments. In the latter experiments a modification[c] of this method was used, which has been shown to give very satisfactory results in the determination of extremely small quantities of alcohol.

The urine, drip water, and freezer water were distilled several times in order to separate the alcohol and other volatile and readily oxidizable organic matters and to obtain them in a more concentrated form. The amount of organic matter (here designated as reducing material) in the distillates was then determined by the method mentioned above. The amount of reducing material in the air current was estimated by passing the outgoing air through bulbs containing concentrated sulphuric acid, and determining the amount of reducing material in the acid. The total amount of reducing material thus determined in the various excretory products was calculated as alcohol.

Other investigators[d] have found evidence that such reducing materials are excreted by the body when no alcohol was ingested. In several experiments in which alcohol did not form part of the diet, examinations of respiratory and excretory products were made the same as when alcohol was given, and reducing materials were found to be present.[e] The average amount found in these experiments without alcohol was, therefore, deducted from the total amount determined in the experiments with alcohol and the difference taken as alcohol excreted, as shown below:

Alcohol ingested and excreted unoxidized.

Alcohol ingested, average 13 experiments	grams..	72.3
Reducing material in excretory products:		
When alcohol was ingested, average 13 experiments	grams..	1.6
When no alcohol was ingested, average 6 experiments	do....	.3
Alcohol excreted	grams..	1.3
Total alcohol metabolized	do....	71
Do	per cent..	98.2

[a] See Bodländer in Arch. Physiol., Pflüger, 32 (1883), p. 424.

[b] Loc. cit.

[c] See Benedict and Norris on "The Determination of Small Quantities of Alcohol," Jour. Am. Chem. Soc., 20 (1898), p. 299.

[d] Dupré, Proc. Roy. Soc. (London), 20 (1871–72), 268. See also Billings, Mitchell, and Bergey on "The composition of expired air and its effect upon animal life." Smithsonian Contributions to Knowledge, XXIX (1895), No. 989.

[e] See Table CXXI in the Appendix.

From Table CXXII in the Appendix it will be observed that the quantities of alcohol eliminated by the lungs, skin, and kidneys varied from 0.7 to 2.7 grams, and averaged 1.3 grams per day. These quantities correspond to a range of from 1 per cent to 3.7 per cent and an average of 1.9 per cent of the total amount of alcohol ingested. We consider, therefore, that in general when alcohol is taken in small doses not more than 2 per cent is given off unoxidized, and the results of the later experiments indicate that this figure is really too large. Accordingly, the coefficient of availability of alcohol is taken as 98 per cent.

Comparing this with the coefficients of availability of protein, fat, and carbohydrates in the diet with alcohol, as given in the Table 12, p. 257, it appears that the coefficient of availability of alcohol in these experiments was practically the same as that of the carbohydrates and larger than those of fats and protein of ordinary food. That is to say, it was found that 2 per cent or less of the total alcohol ingested in these experiments was given off unoxidized by the lungs and skin, while on the average about 2 per cent of the carbohydrates, 5 per cent of the fats, and 7 per cent of the protein of the ordinary diet appeared to be excreted unoxidized.

The conclusion is that in these experiments the alcohol was more completely consumed than are the nutrients of ordinary mixed diet.

METABOLISM OF THE ENERGY OF ALCOHOL.

It was stated above that the experiments with men in the respiration calorimeter had shown a very close agreement between the income and outgo of energy in the body, and that this was regarded as practically a demonstration that the law of the conservation of energy holds in the living organism. Up to April, 1900, the results of 30 such experiments had been obtained. These covered, all told, 93 days; they were made with 4 different subjects, under various conditions of diet and occupation. When the figures for individual days or for individual experiments are considered, there appears to be more or less disagreement between the figures for income and those of outgo energy, though the differences are inside the natural range of error in such physiological experiments. When the results of all the experiments are averaged together, however, the differences counterbalance each other, and the daily income, 2,718 calories, is found to be practically identical with the daily outgo, 2,716 calories. This agreement is in accordance with the law of the conservation of energy, and thus confirms the belief that this law governs the metabolism of energy in the living organism.

In 13 of the 30 experiments referred to alcohol formed a part of the diet. The results of these experiments compared with those without alcohol imply very clearly that the law of the conservation of energy holds as well with the diet containing alcohol as with the ordinary diet. This may be seen from Table 13, which epitomizes the more detailed statistics given in Table CXX in the Appendix, and compares the averages of the results of the rest and the work experiments in which alcohol formed part of the diet with those of similar experiments without alcohol. Both those experiments that are strictly comparable and those less comparable, as explained on a preceding page, are here included.

TABLE 13.—*Metabolism of energy. Averages of results of experiments with ordinary and with alcohol diet.*

Experiments with and without alcohol.	Energy of net income.[a]	Energy of outgo measured as— Heat.	Muscular work.	Total.
MORE DIRECTLY COMPARABLE.				
Rest experiments.	*Calories.*	*Calories.*	*Calories.*	*Calories.*
Without alcohol: Nos. 9, 24, 26, and 28	2,190	2,221		2,221
With alcohol: Nos. 10, 22, 27	2,191	2,221		2,221
Work experiments.				
Without alcohol: Nos. 11, 29 and 31, 32 and 34	3,660	3,451	220	3,671
With alcohol: Nos. 12, 30, 33	3,690	3,461	215	3,676

[a] Estimated energy of material actually oxidized in the body.

TABLE 13.—*Metabolism of energy. Averages of results of experiments with ordinary and with alcohol diet*—Continued.

Experiments with and without alcohol.	Energy of net income.[a]	Energy of outgo measured as—		
		Heat.	Muscular work.	Total.
MORE DIRECTLY COMPARABLE—continued.				
Average of rest and work experiments.	*Calories.*	*Calories.*	*Calories.*	*Calories.*
Without alcohol	2,925	2,836	[b](110)	2,946
With alcohol	2,941	2,841	[b](108)	2,949
LESS DIRECTLY COMPARABLE.				
Rest experiments.				
Without alcohol: Nos. 13 and 14, 5, 21	2,302	2,277	....	2,277
With alcohol: Nos. 7, 15 to 17, 18 to 20	2,356	2,358	....	2,358
Average of all above experiments.				
Without alcohol	2,717	2,650	[b](73)	2,723
With alcohol	2,746	2,680	[b](72)	2,752

[a] Estimated energy of material actually oxidized in the body.
[b] In this average the muscular work of the work experiments is distributed over both the work and the rest experiments, which is of course not strictly logical.

The energy of net income given in the table above represents the energy of the material actually oxidized in the body, as determined from the energy of the food, of the excretory products, and of the body material stored or lost. The energy of outgo is that given off from the body in the form of heat and external muscular work, as measured by the apparatus. According to the law of the conservation of energy, the income and the outgo must be equal. From the comparisons given in the table above it will be seen that, whether the diet did or did not contain alcohol, the outgo was sometimes greater and sometimes less than the income, but the difference in every case was far within the range of variation to be expected in physiological experiments of such nature as these, so that the results may be considered as showing practical agreement. If we counterbalance the variations by averaging the experiments in which alcohol formed part of the diet and those without alcohol, we get the following results:

Daily income and outgo of energy with and without alcohol.

Diet.	Energy of material oxidized in the body.	Energy given off by the body.
	Calories.	*Calories.*
Average 13 experiments, without alcohol	2,717	2,723
Average 13 experiments, with alcohol	2,746	2,752

When the diet contained no alcohol, the energy of the proteids, fats, and carbohydrates burned in the body, averaging 2,717 calories per day, was practically identical with the energy given off by the body in the form of heat, or heat and (the heat equivalent of) external muscular work, averaging 2,723 calories per day. When alcohol formed part of the diet the total energy of the proteids, fats, and carbohydrates burned in the body, added to the energy of the alcohol, averaged 2,746 calories per day, and the energy given off as heat, or heat and external muscular work, averaged 2,752 calories per day. The total kinetic energy of outgo is equal to the total potential energy of income, whether it be with ordinary diet alone, or with ordinary food and alcohol.

To these results there can be but one interpretation. The energy which was latent or potential in the alcohol was wholly transformed in the body, was actually given off from the body, and was exactly recovered as heat or heat and muscular work. Otherwise, how did the body dispose of the energy of the alcohol, and from what other source did it get an exactly equal amount to replace it?

The conclusions, therefore, are:

1. The law of the conservation of energy obtained with the alcohol diet as with the ordinary diet.

2. The potential energy of the alcohol oxidized in the body was transformed completely into kinetic energy, and appeared either as heat, or as muscular work, or both. To this extent, at any rate, it was used like the energy of the protein, fats, and carbohydrates of the food.

THE PROTECTION OF BODY MATERIAL BY ALCOHOL.

General considerations. Previous experiments and their explanation.—The belief was formerly quite general that alcohol has a specific pharmacodynamic action in retarding the metabolism of body material, both fat and proteid. As much of the earlier experimenting implied that alcohol in moderate quantities tends to "prevent waste" or "conserve the tissues," and its oxidation in the body was not understood, this effect was naturally attributed to its action as a drug. Later, as the functions of the nonnitrogenous nutrients of food came to be better understood, and the fact that alcohol is oxidized as they are in the body became fully established, the view has become common that its effect in retarding or protecting metabolism is to be explained by a nutritive rather than a pharmacodynamic action—that, in other words, it tends, by its own oxidation, to prevent the oxidation of other materials. This latter function of alcohol, however, has been denied on two grounds:

1. The increased circulation of the blood through the peripheral capillaries and the fall of body temperature which follows the ingestion of alcohol have led to the theoretical inference that the energy supplied to the body by the oxidation of the alcohol is lost by the extra radiation of heat it causes, so that it can not do the work of the fats and carbohydrates in protecting food or body material from consumption. This ground, however, is hardly tenable since, as shown beyond, the fall of body temperature with ordinary doses is very small, and the amount of extra heat radiated is only a fraction of that supplied by the alcohol.

2. The other ground for doubting the power of alcohol to protect body material from consumption is that of direct experiment. That it may protect fat is generally conceded, but there are a number of reliable experiments on record in which the replacement of the carbohydrates and fats of a ration by alcohol has been followed by an increased elimination of nitrogen. This has been explained by the assumption that alcohol tends to increase rather than diminish the catabolism of protein in the body. On the other hand there is a considerable amount of experimental evidence to the effect that alcohol may and at times does serve as a protector of protein.

As explained in a review of the experimenting upon this subject [a] it seems to us that the conflicting results may be explained by the hypothesis of two opposing tendencies of alcohol, the one pharmacodynamic and the other nutritive. This view makes the former a specific, and sometimes, if not always, temporary action of alcohol, by which it increases the catabolism of protein, while the latter action is that resulting from its oxidation. According as the latter or the former action predominates the alcohol may protect protein or fail to do so. In favor of this theory is the fact that it explains and harmonizes the results of previous experimenting and those of our own experiments also.

In considering the efficiency of alcohol for the protection of body fat and protein it is important to distinguish between two questions. Does alcohol protect these materials at all? Is it equal in protecting power to the isodynamic amount of fats or of carbohydrates, or of a mixture of the two? The comparisons in these experiments are between nearly isodynamic amounts of alcohol and the other ingredients.

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[a] Report of Physiological Subcommittee of Committee of Fifty for the Investigation of the Liquor Problem, Boston, Houghton, Mifflin & Co. (In press at the time of this writing.) See also a more detailed review of the subject by Rosemann. Der Einfluss des Alkohols auf den Eiweissstoffwechsel; Arch. f. d. ges. Physiol., Bd. 86, 1901, pp. 307–503.

The evidence of the experiments here reported.—Although the present experiments were not planned for the study of these particular questions, they throw some light upon them. The details, in their bearing upon the protection or nonprotection of body protein and fat, are brought together in Table CXX in the appendix, and the average results are summarized in Table 14 herewith, which shows the amounts of available protein and energy of the diet and the amounts of protein and fat gained or lost by the body in the experiments with and without alcohol.

TABLE 14.—*Comparison of gains and losses of protein and fat in experiments with and without alcohol.*

Experiments compared.	Serial numbers of experiments.	Total number of days.	Average per day. Available food. Protein.	Average per day. Available food. Energy.	Average per day. Gain (+) or loss (−). Protein.	Average per day. Gain (+) or loss (−). Fat.
MORE DIRECTLY COMPARABLE.						
A and B:						
E. O., rest—			*Grams.*	*Calories.*	*Grams.*	*Grams.*
Average, 2 experiments without alcohol.	9, 24	7	114	2,618	− 1.0	−39.0
Average, 2 experiments with alcohol	10, 22	7	116	2,602	− 2.8	+42.0
D:						
E. O., work—						
1 experiment without alcohol	11	4	110	3,510	− 3.0	−39.7
1 experiment with alcohol	12	4	113	3,614	− 1.0	−32.2
A, B, and D:						
E. O., rest and work—						
Average, 3 experiments without alcohol.	9, 24, 11	11	112	2,915	− 1.6	+12.7
Average, 3 experiments with alcohol	10, 22, 12	11	115	2,939	− 2.2	+17.2
C:						
J. F. S., rest—						
Average, 2 experiments without alcohol.	(26, 28)	6	92	2,253	− 4.0	+23.1
1 experiment with alcohol	27	3	92	2,264	− 6.0	+18.2
E and F:						
J. F. S., work—						
Average, 4 experiments without alcohol.	(29, 31), (32, 34)	12	95	3,251	− 6.1	−27.5
Average, 2 experiments with alcohol	30, 33	6	94	3,235	−14.5	−27.7
C, E, and F:						
J. F. S., rest and work—						
Average, 6 experiments without alcohol.	(26, 28), (29, 31), (32, 34)	18	94	2,918	− 5.4	−10.6
Average, 3 experiments with alcohol	27, 30, 33	9	93	2,911	−11.6	−12.4
A to F (Group I):						
E. O. and J. F. S., rest and work—						
Average, 9 experiments without alcohol.	9, 24, 11, (26, 28), (29, 31), (32, 34).	29	103	2,917	− 3.5	− 1.1
Average, 6 experiments with alcohol	10, 22, 12, 27, 30, 33	20	104	2,925	− 6.9	− 2.4
LESS DIRECTLY COMPARABLE.						
G, H, and I (Group II):						
E. O. and A. W. S., rest—						
Average, 4[a] experiments without alcohol.	(13, 14), 5, 21	14	100	2,239	− 7.3	− 2.3
Average, 7[a] experiments with alcohol	7, (15, 16, 17), (18, 19, 20).	16	98	2,400	− 3.0	− 6.5
AVERAGE OF ALL THE ABOVE EXPERIMENTS.						
A to I (Group III):						
E. O., J. F. S., and A. W. S., rest and work—						
Average, 13 experiments (3 with work) without alcohol.	(13, 14), (26, 28), (29, 31), (32, 34), 5, 9, 11, 21, 24.	43	102	2,691	− 4.8	− 0.1
Average, 13 experiments (3 with work) with alcohol.	7, (15, 16, 17), (18, 19, 20), 10, 12, 22, 27, 30, 33.	36	102	2,750	− 5.6	+ 3.8

[a] When two or more similar experiments are grouped together, the group is counted as 1 experiment in drawing the average. Experiments thus treated are put in parenthesis in the second column; thus, (15 to 17).

The grouping in Table 14 is on the same basis as in the corresponding tables in the preceding pages and in the Appendix.

When the fuel value of the diet is in excess of the needs of the body, the latter often, though not always, increases its store of material. Sometimes this increase is in the form of protein, sometimes fat, and sometimes both protein and fat. When the body requires energy in excess of that supplied by the food, it will draw upon its previously accumulated store of fat or protein, or both, for fuel. Along with the gains and losses of protein and fat are changes in the carbohydrates (glycogen), but the total quantity of these substances in the tissues is relatively small. The present methods of experimenting do not suffice for accurate measurement of the changes of glycogen, and it is commonly left out of account in discussions such as that in which we are now engaged.

PROTECTION OF BODY FAT.

The figures for the individual experiments in Table CXX of the Appendix show in some cases a larger gain or smaller loss of fat without alcohol than with it; in other cases the results are reversed. When, however, the experiments are grouped together and the averages with and without alcohol are compared, it is clear that, except where the differences in fuel value of the diet were considerable, the differences of fat balance are hardly large enough to be of consequence. Taking the experiments altogether, the figures of the tables, and especially those of Table 14, show slight gains in fat both with and without alcohol, but the gain is slightly larger with the alcohol. Thus in Group I, in which the experiments are more directly comparable, the average gain in 9 experiments without alcohol is 1.1 grams, in 6 with alcohol 2.4 grams, making a difference in favor of the alcohol of 1.3 grams. In the less directly comparable experiments there is an average difference of 8.8 grams, and in Group III with all the experiments there is an average of 3.9 grams in favor of the alcohol. It is also to be noted that in general the total energy of the rations with the alcohol average somewhat larger than in those without alcohol. The figures for differences just cited are brought out more clearly in Table 17, beyond, in the discussion of the utilization of energy in the experiments with and without alcohol. The comparison as there made in detail shows on the whole an advantage of the ordinary diet over that with alcohol, though the difference is very small, indeed.

A direct indication of the fat-protecting power of alcohol is found in the series of experiments with E. O., Nos. 22, 23, 24. These were practically three successive periods of 3 days each. In all there was a basal ration with 116 grams available protein and 2,290 calories of available energy. To this ration was added—in the first experiment, alcohol; in the second, nothing; in the third, sugar. The alcohol and sugar each furnished about 500 calories of energy. With the alcohol there was a daily gain of 63 grams of fat; with the basal ration this was reduced to 9 grams; with the sugar it rose again to 60 grams per day. With the sugar there was a gain of 1.7 and with the alcohol a gain of 1.4 grams, while with the basal ration alone there was a loss of 1.6 grams of protein. Leaving this slight gain or loss of protein out of account, the net gain of fat with the alcohol above that in the basal ration was 54 grams, which would make very nearly 500 calories. The net gain of fat with sugar was 51 grams. In this particular case, therefore, with isodynamic quantities of sugar and alcohol, the gain of fat was practically the same with both.

An even more striking illustration of the fat-protecting power of alcohol is found in experiments Nos. 18–21, with A. W. S. as summarized on page 329 beyond. When alcohol was added to a basal ration of ordinary food, the body gained fat at the rate of 21–35 grams per day; but when the giving of alcohol was stopped and the body had only the basal ration, it lost 25 grams of fat per day.

A clearer demonstration of the power of alcohol to protect fat from consumption would be hardly possible than that given in the experiments with E. O. and A. W. S., just cited.

We thus have two kinds of tests of the power of alcohol as compared with that of isodynamic amounts of carbohydrates and fats of the food for the protection of body fat. In every individual case the protecting power of the alcohol is manifest. In some instances it is slightly inferior and in others it is slightly superior in this respect, and on the average it is just about equal to the nutrients which it replaced.

So far as we are aware these are the only experiments in which the power of alcohol to protect fats has been determined by direct quantitative tests. While there are numerous experiments on record which have seemed to indicate that alcohol has this power, we have found none which seem to us to imply the opposite.[a] Fortunately this question, which is one of no little importance, thus seems to be so clearly settled as to require no further discussion. Such is not the case with the similar question regarding the power of alcohol to protect protein from consumption.

PROTECTION OF BODY PROTEIN.

As regards the protection of body protein by alcohol, the results of the experiments are variable, but on the whole the catabolism of protein, as measured by the amount of nitrogen excreted by the kidneys, was slightly larger in the experiments with than in those without alcohol. In discussing the effect of alcohol upon protein metabolism, we must consider the variations from day to day in the amount of nitrogen excreted in the urine when alcohol forms a part of the diet, and compare them with the variations in similar experiments in which alcohol is not included in the diet. The data of the daily eliminations of nitrogen by the different subjects in experiments with and without alcohol are summarized in Table CXXIII in the Appendix.

What especially concerns us here is the influence of the substitution of alcohol for a portion of the ordinary food upon the gain or loss of body protein. As this seems to depend largely upon the individual, it will be well to discuss the experiments with the three subjects separately.

Experiments with E. O.—With this subject there was a marked tendency to excrete more nitrogen in the urine on either the day before or the day after he entered the respiration chamber. This tendency was as noticeable in the experiments without as in those with alcohol. This variation in nitrogen excretion is independent of either the character of the food or the activity of the subject, and appears to be due to a psychic cause that is little understood. Since this variation was often much larger than any which could be attributed to the alcohol, we hesitate to assign to the latter any definite and uniform effect upon the metabolism of nitrogen.

It is to be noted that there is no experiment with E. O. in which an alcohol diet immediately preceded or followed a diet furnishing the same amount of energy from ordinary food materials without alcohol. There are, however, a number of separate experiments which may be compared, as is done in Table 15.

TABLE 15.—*Experiments with E. O.—Gains and losses of body protein and fat with and without alcohol.*

Experiments.	Total number of days.	Average per day.			
		In available food.		Gain (+) or loss (−).	
		Protein.	Energy.	Protein.	Fat.
MORE DIRECTLY COMPARABLE.					
Rest experiments.		*Grams.*	*Calories.*	*Grams.*	*Grams.*
Without alcohol, Nos. 9, 24	7	114	2,618	−1.9	+39.0
With alcohol, Nos. 10, 22	7	116	2,602	−2.8	+42.0
Work experiments.					
Without alcohol, No. 11	4	110	3,510	−3.0	−39.7
With alcohol, No. 12	4	113	3,614	−1.0	−32.2
Rest and work experiments.					
Without alcohol, Nos. 9, 24, 11	11	112	2,915	−1.6	+12.7
With alcohol, Nos. 10, 22, 12	11	115	2,939	−2.2	+17.2

[a] See review of experiments on the effects of alcohol on the metabolism of carbon in the report of the Committee of Fifty referred to on page 261.

TABLE 15.—*Experiments with E. O.—Gains and losses of body protein and fat with and without alcohol*—Continued.

Experiments.	Total number of days.	Average per day.			
		In available food.		Gain (+) or loss (−).	
		Protein.	Energy.	Protein.	Fat.
LESS DIRECTLY COMPARABLE.					
Rest experiments.		*Grams.*	*Calories.*	*Grams.*	*Grams.*
Without alcohol, Nos. 13, 14[a]	7	99	2,294	−12.0	+25.7
With alcohol, No. 7	4	99	2,230	−12.0	−14.3
AVERAGE OF ALL ABOVE.					
Without alcohol	18	109	2,760	− 4.2	+16.0
With alcohol	15	111	2,762	− 4.6	+ 9.4

[a] Nos. 13 and 14 averaged as one experiment.

In the less directly comparable experiments Nos. 13 and 14 are grouped together as one, since the average quantities of protein and energy are the same as in No. 7. The details, however, show that while the quantities of energy in the rations were the same in both, No. 13 had 110 and No. 14 only 89 grams of protein. Nevertheless the results as regards gain or loss of body material were almost identical. In each there was a loss of 12 grams of protein and in No. 13 there was a gain of 27 grams and in No. 14 a gain of 24 grams of fat. The experiments were 40 days apart. We lay especial stress upon this circumstance, because it illustrates the futility of drawing final conclusions from a single experiment. In each of these cases the metabolism experiment was preceded by a period of 4 days with similar diet while the subject was outside the calorimeter, but in neither case was nitrogen equilibrium obtained. Neither one of these experiments, therefore, could be taken as a basis for conclusion as to the quantity of protein required for either nitrogen equilibrium or constant elimination of nitrogen. A special reason for citing them here with No. 7 is that they were made with the same subject as the other experiments of the table.

The chief reliance is to be placed upon the more directly comparable experiments. In those in which the subject was at rest, the alcohol ration furnished 2 grams more protein and 16 less calories of energy per day than the nonalcohol ration. There was a larger loss of protein by 1.8 grams and a larger gain of fat by 3 grams with the alcohol. These differences are all very small, but in so far as they go they imply that the alcohol was somewhat less efficient as a protector of protein than the fats and carbohydrates which it replaced. In the work experiments the alcohol ration supplied 3 grams more of protein and 104 calories more of energy than the other. With both there was a loss of protein, the amount being 3 grams per day without and 1 gram per day with alcohol; but since the alcohol ration furnished 3 grams of protein more than the other, there remains a deficit of 1 gram of protein per day against the alcohol ration as compared with that without alcohol, and that notwithstanding the larger fuel value of the diet. Here again the alcohol ration is slightly inferior in protein protecting power.

Taking the rest and work experiments together, the alcohol rations, with an average of 3 grams of protein and 24 calories of energy per day more than the nonalcohol ration, show a greater loss of protein by 0.6 gram per day. On the other hand there is a slightly larger average gain of fat with the alcohol.

If we reckon the less comparable experiments in the general average, we have 111 grams of protein with alcohol as against 109 grams without it, while the quantities of energy are the same in both rations. The average loss of protein is 0.4 gram greater and the gain of fat 5.6 grams less with the alcohol; but of course much less stress is to be laid upon the less comparable experiments.

On the whole it is clear that in these experiments with this subject the alcohol was not as efficient as isodynamic quantities of fats and carbohydrates in protecting protein. Notwithstanding the energy of the alcohol was actually larger than that of the fats and carbohydrates which it replaced, it did not equal them in protecting power. The difference is the more striking because of the slightly larger average quantities of protein in the alcohol rations. On the other hand, the differences between the amounts of protein and energy in the alcohol as compared with the nonalcohol experiments are so slight as to imply only a slight inferiority of the alcohol in the protection of protein.

While the alcohol was not isodynamically equal to the carbohydrates and fats in protecting power, it would be going very far to deny that the experiments imply a positive protecting action. Not only were the differences in favor of the protecting power of the carbohydrates and fats as compared with the alcohol very small, but the quantity of energy supplied by the alcohol was large. To claim that the alcohol has no protecting power would be to assume that the same reduction of fats and carbohydrates in the rations without any replacement by alcohol would have resulted in no greater differences in protein protection. This is in the highest degree improbable.

In this connection the results of experiments Nos. 22, 23, 24 above referred to are worthy of consideration. With the normal ration, plus alcohol, there was a gain of 1.4 grams of protein and 63 grams of fat per day; but when, in the period immediately following, the alcohol was removed, there was a loss of 1.6 grams of protein and a gain of only 9 grams of fat.

Experiments with A. W. S.—With this subject we have but one series of rest experiments. This consisted of a preliminary period of 4 days, followed by four experimental periods, during which the subject was in the respiration chamber. Throughout the preliminary and experimental periods there was a uniform basal ration of ordinary food, supplying about 90 grams of protein and 2,040 calories of energy. To this was added, in the preliminary period of 4 days, commercial alcohol, furnishing about 500 calories of energy. The nitrogen in the urine during the successive days was 12.2, 16, 19, 16.4 grams; that is to say, there was a marked increase of protein catabolism during the whole period. The first three experiments proper were of 2 days each. In the first of these periods commercial alcohol, in the second whisky, and in the third brandy was added to the basal rations, the quantities being sufficient to furnish the same amount, about 500 calories, of energy. The daily quantities of nitrogen in the urine were 17.4, 15.4, 14.7, 14.2, 13.8, and 14.4 grams; that is to say, the rise in nitrogen excretion continued through the first day of the first period; thereafter it fell. During the fourth period of 3 days the basal ration was given without the alcohol. The nitrogen excretion was 14.5, 16.2, 15.4 grams, thus showing an increase again. The natural inference is that with this subject, who had always been an abstainer, the rise in nitrogen excretion at first was due to the alcohol. The very evident fall after the fifth day implies that the action of alcohol in increasing the nitrogen was transitory, and that it had passed away at the end of the third period. The increase of nitrogen excretion in the fourth period was apparently due to the reduction of the ration by the removal of the alcohol.

The average gains and losses of protein and fat for the separate periods may be tabulated as follows:

Period.	Days.	Alcohol added to basal ration.	Gain (+) or loss (—) grams per day.	
			Protein.	*Fat.*
First	2	Commercial alcohol	—12	+25
Second	2	Whisky	— 0	+35
Third	2	Brandy	+ 2	+21
Fourth	3	None	— 3	—25

We thus have a gradual change from a loss of nitrogen to equilibrium and positive gain with the alcohol, and on its removal a positive loss. With the fat there is a constant gain with the alcohol and marked loss on its removal.

While it would be unwise to generalize from a single series of experiments, the indications here point clearly toward three conclusions: (1) The alcohol at first caused an increase of nitrogen metabolism and loss of body protein, but this effect was temporary: (2) thereafter the alcohol protected body protein; (3) the alcohol protected fat throughout.

Experiments with J. F. S.—With the third subject there was opportunity to observe the immediate effect produced upon nitrogen metabolism by the substitution of alcohol for a part of the ordinary nutrients of the diet. Three series of experiments were made. Each included three periods of 3 days each. In each series the subject received the same basal ration throughout, but in addition thereto enough of either butter, sugar, or alcohol to furnish about 500 calories. In the first series the subject was at rest, and the order of addition was butter, alcohol, sugar. In the second series the subject was at work and received a larger diet, the order being sugar, alcohol, butter. The third series was similar in all respects to the second except that the order was butter, alcohol, sugar.

These experiments were thus better adapted than any of those previously discussed to show the immediate effect of the substitution of alcohol for other nutrients in the diet, and in each case it will be seen that this substitution resulted in a loss (or an increased loss) of body protein, which loss continued through the 3 days of the alcohol period. The subject was unused to alcoholic beverages, and from what has already been said such a loss of protein during the first few days of the alcohol diet was to be expected from the results of other similar experiments. Whether this loss would have ceased on continuing the alcohol diet, as seems to have been the case with A. W. S., the experiments do not show.

Experiments with J. F. S.—Gains and losses of body protein and fat with and without alcohol.

Experiments.	Total days.	Averages per day.			
		In available food.		Gain (+) or loss (−).	
		Protein.	Energy.	Protein.	Fat.
Rest experiments.		*Grams.*	*Calories.*	*Grams.*	*Grams.*
Without alcohol, Nos. 26, 28	6	92	2,253	− 4.0	+23.1
With alcohol, No. 27	3	92	2,264	− 6.0	+18.2
Work experiments.					
Without alcohol, Nos. 29, 31, 32, 34	12	95	3,251	− 6.1	−27.5
With alcohol, Nos. 30, 33	6	94	3,255	−14.5	−27.7
Average of all above.					
Without alcohol	18	94	2,918	− 5.4	−10.6
With alcohol	9	93	2,911	−11.6	−12.4

Thus all of the experiments with this subject would indicate clearly that for periods of 3 days the alcohol was inferior to either fat or carbohydrates as a protector of protein. It should be stated, also, that the loss of body protein with the alcohol was greater than the figures in the table would indicate, for the nitrogen elimination of the period preceding the alcohol was in each case slightly increased by the entrance of the subject into the respiration chamber, while that of the period following the alcohol is increased by the lag in the excretion of the extra nitrogen metabolized under the influence of the alcohol. The lag would, of course, likewise prevent the effect of the alcohol from becoming fully apparent in the first day of the alcohol period. Hence a better idea of the actual effect of the alcohol would probably be obtained by omitting from consideration the first day of each period. The average elimination of nitrogen thus becomes, in the fore periods, 15.5 grams, in the alcohol periods, 17.1 grams, and in the after period, 15.5 grams per day, showing a difference in favor of the ordinary nutrients of 1.6 grams of nitrogen, or 10 grams of protein instead of 6.2 grams, as shown in the preceding table.

It is also noticeable that the loss of body protein under the influence of alcohol was larger with this subject when at work than when at rest. The difference is not great and may be simply accidental. It might, however, be interpreted as indicating that the subject worked to better advantage on the ordinary diet than on the diet of which a part was alcohol. This would accord with the conclusions drawn by Chauveau from experiments on dogs[a] and by Parkes from extended observations on marching soldiers and workingmen.[b]

Summary.—In interpreting these experiments two things are to be considered. One is that the differences between the amounts of nitrogen excreted with and without alcohol are generally very small. The other is that there is good ground for the belief that with persons little accustomed to the use of alcohol it may have a tendency to increase nitrogen metabolism, which may counteract, to greater or less extent, the tendency to protect protein, though, with some persons at least, this action appears to be temporary. The results with the individual subjects may be briefly recapitulated as follows:

With E. O., who was accustomed to the use of moderate quantities of alcoholic beverages, the protein protecting power of the alcohol was apparent, but seemed to be somewhat inferior to that of fats and carbohydrates.

With A. W. S., an abstainer, there was an increase of nitrogen excretion during the first days after the beginning of the alcohol diet, with a resulting loss of body protein, but this action ceased after 5 or 6 days, and thereafter the alcohol apparently protected protein, though the experiments do not show how its efficiency in this respect compared with that of the carbohydrates and fats.

With J. F. S., who was also an abstainer, there was, in each case, an increase of nitrogen excretion and loss of body protein during the 3-day periods in which the alcohol replaced fat or sugar. There was thus a marked inferiority of alcohol in protecting power. The result is similar to that observed with A. W. S. during the first days with alcohol, but the experiments do not show what the effect of continuing the alcohol diet would have been, and they are, therefore, not decisive.

Taking the results of all the experiments together, it may be said that—

1. They offer no evidence to imply that alcohol can not protect protein, though they imply in some cases it may, at least for a time, fail to do so.

2. On the other hand, they give very marked indications of its protein protecting power.

3. They imply clearly that in this respect it was in some cases nearly or quite equal and in others decidedly inferior to the isodynamic amounts of carbohydrates and fats which it replaced.

Other experiments upon the protection of protein by alcohol.—It is clear that the experiments above described are not conclusive regarding the action of alcohol in protecting protein from consumption. They were not planned for the study of this subject. To make the results decisive the alcohol periods should be long enough to eliminate the more or less temporary action of alcohol as a drug; the available energy of the ration of the nonalcohol periods should equal in some cases the total available energy of the alcohol ration, while in other cases it should equal only that of the ordinary food of the alcohol ration, and finally, the experiments should be repeated with different persons and under different conditions. These facts we did not fully understand when the experiments were begun, nor would it have been practicable with the means at our disposal to make such experiments with men in the respiration calorimeter as would be needed for the comprehensive study of the question. Experiments of from twenty to thirty consecutive days seem necessary for the most satisfactory results. For a man to spend so long a time in the respiration chamber of our apparatus would be, to say the least, very tedious, and the cost of such experiments, in labor and money, would have exceeded our available resources. Fortunately, the results obtained by a number of other investigators, while our experiments were being made and since, have done much to clarify the situation as regards the effects of alcohol upon protein metabolism.

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[a] Compt. rend. Acad. d. Sc. Par. 132, pp. 65 and 110.

[b] Proc. Roy. Soc. 20 (1871–72), 402, and monograph "On the issue of a spirit ration during the Ashantee campaign, 1874," etc. London, 1875.

Referring to the above-named reviews of the subject,[a] and especially to that of Rosemann for details and references to the original memoirs, it will suffice here to summarize the results. It appears that:

1. A large number of early experiments have brought conflicting results, some implying the protection of protein by alcohol; others the opposite. Of the former class those of Mogilianski are of especial interest. Of the latter those of Miura, made under the direction of Van Noorden, and those of Schmidt and of Schoeneseiffen, under the direction of Rosemann, have been much quoted. The general plan of experimenting followed by these three investigators consisted in giving the subject an ordinary diet for a time and observing the nitrogen balance. Thereafter, during a period of four to six days, alcohol was used. In Miura's case the alcohol was substituted for carbohydrates in a diet which had been adequate for maintaining nitrogen equilibrium; but with the alcohol the excretion of nitrogen increased and the body lost nitrogen. With Schmidt, alcohol was added to a diet with which nitrogen equilibrium had been maintained; the alcohol did not diminish the excretion of the nitrogen and the equilibrium continued. With Schoeneseiffen, alcohol was added to an inadequate diet with which there was loss of nitrogen; the loss continued with the alcohol.

These experiments have furnished the chief basis for the contention that alcohol can not protect protein. In Miura's case the increase of nitrogen excretion with the alcohol was as large, and, indeed, in one instance very slightly larger, than when the carbohydrates were removed and no alcohol was used in their place. Miura, and after him Rosemann and others, inferred that alcohol was unable to protect protein from disintegration, and went so far as to ascribe to it a positive disintegrating action and to apply to it the term "proteid poison."

2. Neumann, in 1899, made experiments on a similar plan, save that the alcohol period was continued for sixteen days, during which part of the fat of the normal diet was replaced by alcohol. He found that during the first four days of the alcohol period there was no evidence of protein protection; the nitrogen excretion was increased and was as large as during another period when the ordinary ration was reduced and no alcohol was used in its place. Thereafter the nitrogen excretion diminished, and during the remaining twelve days of the alcohol period it was the same as with the normal ration. When the alcohol was removed and nothing substituted the excretion of nitrogen increased as before. Neumann concludes that in his own case the failure of the alcohol to protect protein at first was probably due to a specific though temporary action by which it tended to increase the disintegration of protein so that the tendency to protein protection was counteracted. Later this special action disappeared and the protecting action came into full play.

Neumann's interpretation of his experiments was questioned by Rosemann, who has been a most vigorous opponent of the theory that alcohol can protect protein, and a keen critic of the experiments which have seemed to favor this view. He maintained the disintegrating, but questioned the protecting action of the alcohol, alleging defects in the plans of Neumann's experiments. Neumann, without replying, repeated his experiments in such ways as to meet Rosemann's objections, and found conclusive evidence of the protecting power of the alcohol, these later results being published early in 1900. In 1901, Chotzen, working under the direction of Rosenfeld, and in 1901, Clopatt, each published results of inquiries which agreed with Neumann's. Meantime Rosemann made several series of experiments of his own, the outcome of which, to his surprise, clearly demonstrated the protecting power of alcohol, and confirmed the views maintained by Neumann. He has taken the pains to prepare an extensive summary of the experimenting in this field,[b] in which he assents fully to the interpretation placed by Neumann, Rosenfeld, Chotzen, and Clopatt upon their experiments; believes that the protection of protein is shown by other experiments, as those of Mogilianski; considers it fully demonstrated by his own experiments; and

[a] Rosemann interprets two of our experiments, Nos. 7 and 10, the only ones then published, as not showing the protection of protein; an interpretation from which we should not dissent, since No. 7 was exceptional, and two experiments could hardly suffice for the establishment of the principle.

[b] See page 261.

comes to the definite conclusion that alcohol has a twofold influence upon the metabolism of protein, as previously suggested by Neumann. He is inclined to believe, with Neumann, that the disintegrating action is most apt to occur with persons little accustomed to the use of alcohol, and is of short duration, while in its action as a protector of protein it is analogous to the carbohydrates and fats, its influence being due to the utilization of its energy by the body. According to this view, the results obtained by Miura and others, in whose experiments the alcohol periods continued only from four to six days, are explained by the disintegrating action of the alcohol, which counteracted the protecting action, so that the resultant effect was an apparent failure of the alcohol to protect protein. With Neumann the alcohol periods continued after this disintegrating action ceased, and showed the more permanent protecting influence. The fact that in a number of the experiments the protecting influence was manifested from the start is explained by the absence or only partial action of the disintegrating tendency.

We have, then, a clearly defined theory regarding the influence of alcohol upon proteid metabolism. This theory assumes two different kinds of action of alcohol. In the one it is a direct protector of protein, and serves the body as food; in the other it tends to disintegrate protein, and acts as a drug. The belief in the first action follows as a corollary from the oxidation of alcohol in the body and the transformation of its energy. In undergoing these changes alcohol is similar to sugar, starch, and fat, which, by their own oxidation and consequent supply of energy to the body are able to protect the constituents of the food and of the body, including protein, from oxidation. That alcohol may and does protect protein is abundantly demonstrated by the experiments above cited.

The disintegrating influence of alcohol upon protein is less definitely proven. The theory is little more than a convenient hypothesis for explaining the failure of alcohol, under some circumstances, to protect protein. It is the only satisfactory hypothesis which has thus far been suggested. It is all the easier to accept because of the considerations that the breaking up of protein compounds in the body seems to be influenced, in some unexplained way or ways, by the nervous system, and this latter in turn is influenced by alcohol. In our own experiments, for instance, the excretion of nitrogen is apparently affected at times by the mental condition of the subject.

In large enough doses alcohol has a paralyzing effect, and may thus reduce general metabolism to a minimum and cause coma or even death. There is no proof that it can not, on the other hand, increase proteid metabolism.

The positive proof of the disintegrating action of alcohol upon protein is limited in amount. The experimental demonstration must be sought in cases in which more protein is broken down with alcohol than without it, the ration of ordinary food being otherwise the same in both cases. We have been able to find only three cases on record in which the amount of protein thus broken down with alcohol apparently exceeded by more than 0.1 gram of nitrogen per day the amount broken down without alcohol. They are discussed in the review above referred to. The first was in one of Miura's experiments, in which the excess with alcohol amounted to 0.5 gram of nitrogen (3.2 grams of protein) per day during an alcohol period of four days. The second was in one of Neumann's experiments, in which the excess during the first four days of an alcohol period of ten days was 0.9 gram of nitrogen per day. During the remaining six days of the same period the nitrogen excretion was less by 1.5 grams per day than in the corresponding period without alcohol. The third was in an experiment by Clopatt. During the first six days of an alcohol period of twelve days the nitrogen excretion exceeded that of a corresponding period without alcohol by 2 grams per day. During the remaining six days of the same alcohol period the nitrogen excretion was less by 1.4 grams per day than it was without alcohol.

It seems to the writers that in view of the unavoidable irregularities in the nitrogen balance in such experimenting these data are insufficient to demonstrate the disintegrating action of alcohol, but, taken in connection with the need of an explanation for the occasional failure of alcohol to protect protein, they make the theory plausible.

Sources of uncertainty in this kind of experimenting.—One point which has hardly received the attention it deserves in discussions of this kind is the uncertainty of the nitrogen balance in any given case as a measure of the actual influence of a given condition upon nitrogen metabolism. This has been emphasized elsewhere in the present memoir (see pp. 393 and 394). Differences which look large in a table of figures are often far inside the unavoidable variations in actual experimenting.

Even when the differences are significant the interpretation may be erroneous. A striking illustration of the danger of such error is found in the current discussion of the question we are now considering. For a number of years past writers upon this subject have insisted most positively that alcohol, instead of being a protector of protein, is a protein poison. This theory is based almost wholly upon the experiments of Miura, Schmidt, and Schoeneseiffen. The experiments of Neumann, Rosenfeld–Chotzen, Clopatt, and Rosemann, not to speak of others, including our own, have shown that this theory was wrong and have given us a very plausible hypothesis to explain why it was wrong.

We can not insist too strongly upon the danger of drawing positive conclusions from figures for nitrogen balance as a measure of protein protection by either alcohol or sugar or starch or fat. Certainty comes only with careful planning and execution and manifold repetition of experiments.

Incidentally, it is to be noted that the excretion of nitrogen in the urine is not necessarily an exact measure of the amount of proteid broken down in short periods, since the time between the disintegration of the protein and the appearance of the nitrogen in the urine, the so-called nitrogen lag, varies widely. The longer the experimental period the less the error from this source.

Finally, there is the unsettled question as to how much of the protein metabolized is that of food and how much comes from organized tissue.

Final conclusions regarding the influence of alcohol upon protein metabolism.—The experiments and considerations above cited seem to us to warrant the following conclusions:

1. The power of alcohol to protect the protein of food or body tissue, or both, from consumption is clearly demonstrated. Its action in this respect appears to be similar to that of the carbohydrates and fats; that is to say, in its oxidation it yields energy needed by the body, and thus saves other substances from oxidation. In this way alcohol serves the body as food. Just how moderate quantities of alcohol compare with isodynamic amounts of sugar, starch, and fat in the power to protect protein from catabolism is not yet settled. Apparently it is in some cases equal, in others inferior, to these substances. It is by no means certain that the fats and carbohydrates are always equal to each other in this power.

2. Alcohol appears also to exert at times a special action as a drug. In large quantities it is positively toxic, and may retard or even prevent metabolism in general and proteid metabolism in particular. In small doses it seems at times to have an opposite influence, tending to increase the disintegration of protein. This action, though not conclusively demonstrated, is very probable. It offers a satisfactory explanation for the occasional failure of alcohol to protect protein, the assumption being that the two tendencies counteract each other. The only justification for calling alcohol a proteid poison is found in this disintegrating tendency. This pharmacodynamic action of alcohol appears to be temporary and most apt to occur with people little accustomed to its use. The circumstances under which such action occurs can not now be fully defined.

Influence of coffee upon protein metabolism in these experiments.—In some of these experiments alcohol was administered with coffee, in others with water. It might be thought that the presence of the coffee would interfere with the action of the alcohol.[a] The figures give no support for this view, as is shown in the following tabular statement.

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[a] See Woodbury and Egbert, A Physiologic Consideration of the Food Value of Alcohol, Jour. Am. Med. Assc., Mar. 31, 1900.

Elimination of nitrogen in presence and absence of coffee.

[Quantities per day.]

Kind and number of experiments.	Days.	Nitrogen. In food.	Nitrogen. In feces.	Nitrogen. In urine.	Nitrogen. Gain (+) or loss (−) to body.
I. With coffee:		*Grams.*	*Grams.*	*Grams.*	*Grams.*
Average 4 experiments with alcohol [10, 12, 18, 22]	13	18.6	1.2	18.2	−0.8
Average 4 experiments without alcohol [9, 11, 21, 24]	14	18.6	1.5	17.5	−0.4
Increase (+) or decrease (−) with alcohol	......	0	−0.3	+0.7	−0.4
II. Without coffee:					
Average 5 experiments with alcohol [(19, 20), 27, 30, 33]	13	15.8	1.0	16.1	−1.3
Average 7 experiments without alcohol [21, (26, 28), (29, 31), (32, 34)]	21	15.9	1.0	15.7	−0.8
Increase (+) or decrease (−) with alcohol	......	−0.1	0	+0.4	−0.5
Increase (+) or decrease (−) in presence of coffee	......	+0.1	−0.3	+0.3	+0.1
III. Direct comparison, alcohol with and without coffee:					
Experiments 15, 17, 18, alcohol given with coffee	6	16.5	0.9	16.0	−0.4
Experiments 16, 19, 20, alcohol given without coffee	6	16.5	1.0	14.9	+0.6
Increase (+) or decrease (−) in presence of coffee	......	0	−0.1	+1.1	−1.0

This table comprises all of the experiments that are directly comparable. The experiments in which the alcohol was given with coffee are averaged together and compared with the corresponding nonalcohol experiments, and the figures in the third line of category I show the effects of alcohol in presence of coffee. Under II a similar comparison is made of the experiments in which no coffee was given, the third line of figures here showing the effects of alcohol when taken alone. By subtracting the third line of figures under II from the corresponding figures under I we obtain values which may be taken as showing the influence of the coffee. A more direct comparison of results with and without coffee is given under III, but the number of experiments compared is necessarily smaller, and therefore individual variations have relatively much greater weight. While the differences which could be attributed to the coffee are probably within the limits of experimental error, it would seem that if there is any effect it is to increase rather than to retard proteid metabolism.

EFFECT OF ALCOHOL UPON THE RADIATION OF HEAT FROM THE BODY.

A current theory maintains that although alcohol supplies heat to the body it also increases the radiation of heat from the body, so that much or all the energy it supplies is wasted.

This theory is based upon two kinds of evidence, which are well attested and make it very plausible. One is the distension of the blood vessels which cause the flush of the skin when alcohol is taken. The other is the lowering of the temperature of the body after the ingestion of alcohol, which is shown by many of experiments and is explained by the loss of heat.

Some writers even go so far as to claim that the extra heat radiation due to the distension of the peripheral vessels is greater than the heat supply from the oxidation of the alcohol. According to this view, alcohol, instead of being a source of energy, is a cause of its loss to the body.

The difficulty with the theory is the exaggeration of the influence of small quantities of alcohol in increasing heat radiation. While the temperature of the body has been found to fall considerably after the ingestion of large doses of alcohol, and especially under exposure to great cold, the effect of ordinary doses is slight and often imperceptible.

In the experiments here described the determinations of body temperature were made with an ordinary clinical thermometer in the mouth and axilla, as elsewhere stated. This method, which is the one ordinarily followed, does not give results as accurate as are to be desired. In some of the earlier experiments, especially with E. O., the observations are of doubtful value. Steps have been taken in this laboratory to devise a thermometer and method of observation which will show more accurately the variations of internal temperature of the body.[a] Meanwhile, as may be seen from the detailed figures, it is clear that the observations do not imply that the bodily temperatures with and without alcohol were greatly different. This agrees with the results of other observations.[b]

The alcohol used in these experiments was equivalent to about 72 grams of absolute alcohol per day taken in 6 doses. This is about the amount contained in an ordinary bottle of wine with 10 per cent alcohol or 3 or 4 glasses (6 or 8 ounces) of whisky.

If we use our own observations and the others just referred to as a basis, it would seem that the fall of body temperature produced by such amounts of alcohol might ordinarily range from nothing to one-half of a degree centigrade. The heat which the body of an average man would have to lose in order to reduce the temperature one-half of a degree might be roughly calculated as follows:

We may take the weight of the body of the average man at 148 pounds, or 67 kilos. The specific heat of the body is not exactly known, but may be estimated at 0.83. On this base a fall of temperature of one-half of a degree centigrade would correspond to $\frac{1}{2}$ (67 x 0.83), or about 28 calories. Of the 72 grams of alcohol, 98 or 99 per cent, or between 70 and 71 grams, would be burned in the body, and would yield at 7.1 calories per gram about 500 calories of heat. By this estimate, if the 72 grams of alcohol were taken in one dose and caused a lowering of the body temperature by one-half of a degree, the 28 calories of heat wasted in the extra radiation due to the alcohol would be one-eighteenth the amount supplied by its combustion.

This method of calculating the amount of heat which the body must lose in order to produce a given fall of temperature is hardly correct. It would be so if we had to do only with a fixed amount of heat at the outset and a fixed amount of loss. But, as a matter of fact, the body is constantly gaining heat from the oxidation of material from within and constantly losing not only by outward radiation, but in other ways, as in the exhalation of air and water, vapor in respiration, in the excretions of the kidneys and intestine, and in the evaporation of water from the skin. The actual temperature depends upon the income and outgo of heat. The income depends upon the material oxidized in the body. The outgo is regulated to a greater or less extent by processes which are not fully understood, but in which the nervous system is the important agency.

Experimental inquiries.—Meanwhile we may consider the experimental evidence bearing directly upon the question of the radiation of heat with and without alcohol.

In a series of experiments by Reichert with dogs the effect of alcohol on the radiation of heat was tested.[c] The experimental periods were, however, only 5 or 6 hours each, and there was no complete comparison of the effects of different diets. The rate of heat radiation and the change of body temperature were carefully observed. The results implied a probable but at most very small increase of heat radiation as the result of administering alcohol.

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[a] F. G. BENEDICT and J. F. SNELL, Eine neue Methode um Körpertemperaturen zu messen. Archiv. f. d. ges. Physiologie 88, p. 492 (1901).

[b] The results of the most reliable observations are well summarized by PEMBREY (Schaefer's Physiology, I, 820) in the following statements:

"Various observers have found that alcohol taken in ordinary quantities as a beverage causes a slight depression, generally less than half a degree, in the temperature of healthy men. On the other hand, poisonous doses may cause a fall of 5° or 6°—in fact, many of the lowest temperatures recorded in man have been observed in drunken persons exposed to cold. See DAVY, *Phil. Trans.*, London, 1850, p. 444; LICHTENFELS and FRÖHLICH, *Denkschriften d. k. Akad. d. Wissensch.*, Wien, 1852, Bd. iii, Abth. 2, S. 131; LALLEMAND, PERRIN, and DUROY, 'Du rôle de l'alcool et des anesthésiques dans l'organisme,' Paris, 1860; OGLE, *St. George's Hosp. Rep.*, London, 1866, vol. i, p. 233; RINGER and RICKARDS, *Lancet*, London, 1866, vol. ii, p. 208; CUNY BOUVIER, *Arch. f. d. ges. Physiol.*, Bonn, 1869, Bd. ii, S. 370; GODFRIN, 'De l'alcool, son action physiologique, ses applications thérapeutiques,' 1869; WECKERLING, *Deutsches Arch. f. klin. Med.*, Leipzig, 1877, Bd. xix, S. 317; ZUNTZ, *Fortschr. d. Med.*, Berlin, 1887; GEPPERT, *Arch. f. exper. Path. u. Pharmakol.*, Leipzig, Bd. xxii, 36; PARKES and WOLLOWICZ, *Proc. Roy. Soc. London*, 1870, vol. xviii, p. 362, found that alcohol in ordinary quantities had no effect on the temperature of a healthy man."

[c] Therapeutic Gazette, February, 1890.

The experiments with men in the respiration calorimeter here described give extended data regarding both the consumption of fuel and the radiation of heat. The details are summarized in Table CXX in the appendix. The final outcome is simple and may be illustrated by two cases, Groups A and D. In each there were two experiments, practically alike, save that one was with ordinary diet and the other with a diet in which part of the fats and carbohydrates were replaced by alcohol as above described. In Group A the subject was at rest, i. e., doing no external muscular work. The potential energy of the material burned in the body and the amounts of heat given off in calories were practically the same, as is shown by the figures herewith. The differences in the results without and with alcohol are entirely within the limits of ordinary variation:

Comparison of energy of material metabolized and heat given off per day in rest experiments with and without alcohol.

Diet.	Energy of material burned.	Energy given off by the body as heat.
	Calories.	*Calories.*
Without alcohol, experiment No. 9	2,277	2,309
With alcohol, experiment No. 10	2,268	2,283

If the alcohol had caused increased radiation of heat, more heat would have been given off from the body and more fuel would have been required, and naturally more would have been burned in the alcohol experiment than in the other. Such, however, was not the case.

In the experiments of Group B the man was engaged for eight hours a day in active muscular work, driving a stationary bicycle. The amount of work was such that he burned enough fuel to yield in all 3,900 calories, and, as the food did not supply enough, he used up some of his store of body fat. The results of such experimenting imply that when the body has not enough food for its support and is forced to draw upon its reserve capital, it uses the materials economically. The energy given off from the body was in two forms—heat and external work. This work was practically the same in both experiments and is reckoned with the heat in the energy given off.

Comparison of energy of material metabolized and heat given off per day in work experiments with and without alcohol.

Diet.	Energy of material burned.	Energy given off by the body as heat and muscular work.
	Calories.	*Calories.*
Without alcohol, experiment No. 11	3,901	3,922
With alcohol, experiment No. 12	3,932	3,927

Here again there was slightly more fuel burned per day with alcohol than without, though the difference was small, while the amount of heat given off was practically the same in the one case as the other. So far as the disposal of the energy is concerned, the figures imply that alcohol was used as economically as the fat, sugar, and starch which it replaced, and that it caused no increased radiation of heat.

We have, all told, 13 experiments with alcohol, covering 36 days. For purposes of comparison these have been grouped, as already explained (p. 241), with 13 experiments without alcohol, covering 43 days.

The subject in 5 of these groups, E. O., was a man who had been long accustomed to the moderate use of alcoholic beverages. The subjects in the other four groups, A. W. S. and J. F. S., were two men who had always been total abstainers.

The results are summarized in the table herewith, which is condensed from Table CXX of the appendix. The first column gives the figures for energy for material actually oxidized. The figures in the second column show the relation between the averages of experiments with alcohol and those without alcohol, the latter being taken as a basis (100 per cent). The corresponding values for total and proportional energy measured as heat in the two classes of experiments are shown in the last two columns of the table. Thus, in the average of all the experiments without alcohol the energy of the material actually oxidized was 2,717 calories. In the average of all the experiments with alcohol it was 2,746 calories. The latter was 101.1 per cent of the former.[a]

TABLE 16.—*Comparison of energy of material oxidized and heat given off in experiments with and without alcohol.*

[Averages per day.]

	Energy of material oxidized.		Heat given off.[b]	
	Calories.	*Per cent.*[c]	*Calories.*	*Per cent.*
EXPERIMENTS MORE DIRECTLY COMPARABLE.				
Average of work and rest experiments.				
Without alcohol (9 experiments)	2,925	100.0	2,946	100.0
With alcohol (6 experiments)	2,941	100.5	2,949	100.1
EXPERIMENTS LESS DIRECTLY COMPARABLE.				
Average of rest experiments.				
Without alcohol (4 experiments)	2,302	100.0	2,277	100.0
With alcohol (7 experiments)	2,356	102.4	2,358	103.5
AVERAGE OF ALL ABOVE EXPERIMENTS.				
Groups A–I.				
Without alcohol (13 experiments)	2,717	100.0	2,723	100.0
With alcohol (13 experiments)	2,746	101.1	2,752	101.1

There was slightly more fuel burned and more heat given off from the bodies of the men when they had alcohol in their diet than when they had the same amount of protein and energy in a diet without alcohol, but with conditions otherwise similar. The differences, however, were very small; in the more directly comparable experiments the excess of fuel burned with the alcohol diet, as measured in calories, was only five parts and that of heat given off only one part in 1,000. In the less directly comparable experiments the differences were larger, but still small.

The quantities of total food were generally below rather than above the requirements of the body, especially in the work experiments, as may be seen from Table CXX of the Appendix. The general results of experiment imply that under such circumstances the body makes economical use of its food and its reserve supply of material. The fact, therefore, that under these conditions the oxidation of material and radiation of heat were so nearly the same with the rations with and without alcohol add still greater force to the comparison.

The conclusion is that in these experiments, with three different men at rest and at work, when 72 grams of alcohol per day taken in six doses and furnishing 500 calories of energy replaced the isodynamic amounts of fats and carbohydrates, the alcohol caused no considerable increase in the amount of heat radiated from the body.

If the alcohol in these experiments had all been taken at one dose, it might have caused the cutaneous vessels to dilate, stimulated the sweat glands (?), and increased the circulation, and thus increased the heat radiation. If there had been enough to cause the ordinary symptoms of intoxication, and especially if it had sufficed to induce the comatose condition for which the expression "dead drunk" is used, and if the men had at the same time been exposed to severe

[a] A difference so small as this is well inside the range of unavoidable error in single experiments. It is only where a large number of such experiments are averaged that differences of one or two parts in one hundred could probably be regarded as significant.

[b] Including heat equivalent of external muscular work in the work experiments.

[c] Of amount oxidized without alcohol.

cold, the production of heat in the body might have been retarded, and the radiation increased so as to lower the body temperature by several degrees.

RAPIDITY OF COMBUSTION OF ALCOHOL IN THE BODY.

There is a popular impression that alcohol is burned in the body much more rapidly than ordinary food, and that in consequence not only is the energy resulting from its oxidation wasted, but derangements of bodily functions may result from the rapid combustion of the alcohol. The exact grounds for the belief or nature of the supposed disturbances we have not seen distinctly stated. Nevertheless, as the impression prevails to some extent, at least among physicians and physiologists, it seems to demand consideration.

Leaving out of account the unsettled question as to how soon after the ingestion of the alcohol its oxidation begins, the main problem is the rate of oxidation. If it is especially rapid, either one of two results may follow. The oxidation of other materials may go on as usual, in which case the total production of carbon dioxid and heat will be abnormally large: or the oxidation of other substances may be diminished so as to compensate for more or less of the oxidation of the alcohol, in which case the rate of production of carbon dioxid and heat may be little, if any, larger than without the alcohol. The natural test will be found in the measurement of these rates of production. So far as we are aware no adequate tests of this character have thus far been made.

In examining the literature of the subject we have not succeeded in finding any experimental proof that the rate of elimination of carbon dioxid or heat from the body is materially increased or decreased by moderate quantities of alcohol. Satisfactory tests would involve the measurement by short periods, as, for instance, hour by hour. Our own experiments were not planned for this purpose, and the measurements were made generally in six-hour periods. There was nothing in the observations to imply that the rate of production of either carbon dioxid or heat was materially increased either immediately after the ingestion of the alcohol or later.

Part of the heat given off from the body is carried away in water vapor given off from the lungs and skin, but the larger portion finds its way to the water current, by which it is carried out of the chamber. The rate of flow of this current and its rise of temperature in passing through the chamber thus measure the rate of evolution of heat from the body other than that carried away by water vapor.

The observations of rate of flow and rise in temperature are made every few minutes, and thus show the rate of evolution of the larger portion of the heat.

We have taken the pains to calculate the evolution of heat for hourly periods for three series of experiments, in which the alcohol diet and ordinary diet were compared, viz, Nos. 22–24, 26–28, 29–31. The calculations, however, have been limited to the night periods between 7 p. m. and 7 a. m., because the evolution of both carbon dioxid and heat is much more regular by night than by day, and any disturbance, such as might be caused by the rapid oxidation of alcohol, would be more easily detected in comparing the figures for the experiments with and without alcohol during the night periods.

The results of these comparisons are negative. There are practically no more irregularities or indications of disturbance in the alcohol than in the nonalcohol experiments. There is nothing in the figures which seems to us to indicate any appreciable tendency toward increase of heat production during the first, second, or third hour after the ingestion of the alcohol. The figures are, indeed, so destitute of such indications as to hardly warrant their printing.

We are therefore led to the conclusion that in these experiments either the alcohol was not suddenly or rapidly oxidized, or if there was such rapid oxidation, there was a corresponding decrease in the oxidation of carbohydrates, fats, or protein.

It is interesting to note that this conclusion accords with the other observations, viz, those of the total heat production and the economy of the use of energy in the rations with or without alcohol. All of these imply that the alcohol, carbohydrates, and fats simply replaced one another as sources of energy: that as either was oxidized the others were proportionately spared.

ALCOHOL AS A SOURCE OF HEAT IN THE BODY.

In the rest experiments the heat given off from the body was equivalent to the total potential energy of the materials oxidized. This was as true in the experiments in which alcohol made part of the diet as in those with ordinary food exclusively. The alcohol must therefore have contributed its full quota of heat as truly as did the starch or fat, and all its potential energy was converted into heat within the body.

In the work experiments the same principle applies, and it follows that unless all the potential energy of the alcohol was converted directly into that of external muscular work part must have been converted into heat within the body. But the total energy of external muscular work was at most the equivalent of 280 calories, while the energy of the alcohol was about 500. Even if all the external work was done at the expense of the alcohol, there would remain 220 calories which must have been transformed into heat within the body. But it is extremely improbable that the alcohol supplied all and the ordinary food none of the energy of external work. In so far, therefore, as the latter came from the ordinary food, more than 220 of the 500 calories of the alcohol must have reached the form of heat within the body.

We have to do here with the question: Of the total energy which was potential in the alcohol and was made kinetic by its oxidation, how much was transformed directly into heat and how much was first changed to the energy of muscular and other bodily work, internal and external, and was afterwards transformed into heat? This involves two fundamental problems. One is the still unsettled physiological question as to whether the production of muscular energy in general is or is not a direct transformation of potential into mechanical energy. The other is the more specific question as to whether the energy of alcohol is like that of the ordinary nutrients of food in its transformation into muscular energy. Both will be referred to beyond in the discussion of alcohol as a source of muscular energy. Meanwhile it is safe to say that:

1. Unless all the potential energy of the alcohol was transformed directly into the energy of internal work in the rest experiments or into that of internal and external work in the work experiments, a supposition that seems highly improbable, part must have been transformed directly into heat in the body.

2. Whether the potential energy was first transformed into muscular energy or not, the whole in the rest experiments and part at any rate in the work experiments reached the form of heat within the body.

The conclusion is that in all these experiments alcohol was a source of heat for the body.

ALCOHOL AS A SOURCE OF MUSCULAR ENERGY.

General considerations.—The question whether or not the energy of alcohol is used for muscular work is not yet definitely answered. The experiments thus far made do not provide means for tracing the energy of the alcohol through the changes it undergoes in the body, and finding how much of it becomes muscular energy. Nor is it easy to devise such experiments. The difficulty is that the potential energy of the alcohol is transformed along with that of other materials oxidized, and there is no known way of separating the kinetic energy which comes from the alcohol from that which is supplied by the carbohydrates or fats or protein. While there is no evidence of any differences between the energy from the several sources, the absolute proof that no such differences exist is not yet at hand.

Back of this is the more fundamental question as to how muscular energy is produced. Concerning this two theories are held. One is that part of the potential energy of the food and body material oxidized is converted directly into the mechanical energy exerted by the muscle. The other is that the contraction of the muscle, by which its work is done, is due to heat. According to this view, practically all of the potential energy is first transformed into heat and a part afterwards appears as muscular energy. If the second view is correct, it is hard to see how the heat derived from the oxidation of the alcohol should be in any way different from the rest of the heat. If the muscular energy is the first product of the transformation of potential energy, it is conceivable that there might be some attribute of alcohol which would prevent its potential energy from being changed into mechanical energy. But there is nothing in the results of experiment to imply any such difference between alcohol on the one hand, and sugar, starch, or fat on the other. The case regarding the transformation of energy is like that just referred to regarding the use of the energy after it is transformed. There is no evidence of any difference between alcohol and other nutrients in either respect, but there is no proof that the difference does not exist.

The most satisfactory method of study of this question as to whether alcohol can be a source of the mechanical energy exerted by the muscles is by measuring the amounts of different substances metabolized and the amounts of muscular work done, and thus getting light upon the comparative efficiency of the several substances as parts of a diet for muscular work.

If the experiment could be made with lean meat and alcohol in such a way that the body could obtain no other fuel than alcohol and protein, and the energy of the internal and external muscular work should be found to exceed that of the protein, it would be clear that the rest of the muscular energy must come from the alcohol. But as yet we have no means for measuring the internal work, and it would probably be difficult to find a man who could do much external work day after day on such a diet without drawing upon the store of material in his body.

For the present, therefore, we are limited to experiments in which other fuel is burned with the alcohol, and our conclusions must depend upon measurements of (1) the energy supplied by each kind of fuel, (2) the energy given off from the body, and (3) the amount of muscular work performed.

Here again we meet a difficulty, namely, that of measuring the muscular work. We have to do with two kinds of work, external and internal. The external work is that which is performed outside of the body, as, for instance, the power which a man riding a bicycle applies to the pedals. This is capable of quite accurate measurement. Such measurements were made in the experiments here described. By internal work is meant that of circulation, respiration, digestion, etc. Thus a not inconsiderable amount of energy must be used for the muscular contractions of the heart by which the blood is pumped out through the arteries and back from the veins. It is held by some physiologists that a large portion of the total energy supplied by the food is used for this internal physiological work. At present no exact method is known for measuring the internal work of the body. It is transformed into heat before it leaves the body and in the experiments with the respiration calorimeter it is collected and measured as part of the total heat given off. But this total heat includes also the heat which was produced in the body and not used for muscular work, and no way has yet been found to distinguish between the heat which has and that which has not been used, and to measure the two quantities of heat separately.

We know from measurements of the external muscular work that it represents at most a fraction, and generally a small fraction of the total energy transformed. It may be that in the case of a man doing a large amount of muscular labor this external work added to the internal work would account for the larger part of the total energy transformed in the body.

The measurements of income of energy from the oxidation of ordinary nutrients and alcohol and of outgo of energy in the different forms of heat and external muscular work therefore do not answer the specific question as to how much of the energy provided by the alcohol is used for either internal or external muscular work, or both.

Economy of utilization of the energy of the rations with and without alcohol.—We may nevertheless get some light on the question by putting it in another way: Is the total energy of the ration used as economically when part of it is supplied by alcohol as when the whole comes from ordinary food? The question may be approached in two ways, (1) by considering the differences in the amounts of available energy in the diets with and without alcohol, and comparing these with the energy in the body protein and fat gained or lost in the two cases, and (2) by comparing the energy of material actually oxidized in parallel experiments with and without alcohol. The principles here involved may be explained as follows:

The energy needed and used by the body.—The body requires and uses a certain amount of energy. This amount is larger when the man is at work and smaller when he is at rest. The larger the amount of energy used, the more material will be metabolized to furnish it. If the available nutrients of the food exceed the amounts metabolized, the excess will be stored in the body. Assuming the store of carbohydrates to remain constant, the body will gain protein or fat or both. Translating this last statement from terms of material to terms of energy, if the available energy of the food exceeds the energy metabolized, the amount of energy in the body will be increased by the storage of energy in protein or fat. On the other hand, if the available energy of the food does not supply the demand, the lack will be made up by drafts upon body protein or fat. We thus have two measures of the energy used by the body. One is the gain or loss of body protein and fat with a given amount of available energy in the food. The other is the total energy metabolized whether it be more or less than the available energy of the food.

Economy of utilization of energy.—We have distinguished between the energy needed and that actually metabolized. If the body uses the energy economically it does not metabolize more than it needs. But it does not always make the most economical use of either material or energy. If it has more food than it needs, it may use this wastefully. Part of the excess of material, at times perhaps the whole, may be stored for future use, but often more or less of the excess is simply consumed and the energy wasted. On the other hand, if the food only equals the demand, and especially if it falls short and body material has to be drawn upon, the body will probably make economical use of the energy of both food and body material. This was the case in the experiments now under discussion. When the men were at rest the food supplied but little more, and when they were at work it supplied less, than was actually needed. In these experiments, therefore, the two measures just referred to, namely, the energy of body material gained or lost and the total energy metabolized, show how much the body uses when the energy is economically utilized.

To state the case in another way, either the energy of material gained or lost with the given diet, or the energy of the total material oxidized, gives a measure of the energy actually employed for economical use. These quantities can be expressed in calories.

Comparative economy of energy of different materials.—This brings us to the question at issue. Is the energy of alcohol equal, superior, or inferior in value to that of carbohydrates or fats or other nutrients of ordinary food as part of a diet for rest or for muscular work? Will a calorie of energy from alcohol go as far, farther, or not as far as a calorie from sugar, starch, fat, or protein in meeting the actual needs of the body? The answer is to be sought in the experiments in which a diet of ordinary food is compared with a diet containing alcohol, the total available protein and energy of the food and the other conditions being the same in both experiments. The test will be found in the gains or losses of body protein and fat, and in the total energy metabolized in the two experiments. Any differences in either of these factors, to wit, (1) gains or losses of body material, or (2) energy metabolized, provided they are outside the limits of experimental error, must be attributed to the diet; that is to say, the alcohol in the diet. If the body gains or loses the same amount of material, or if it metabolizes the same amount of energy with both diets, a calorie of energy from one is equal to a calorie of energy from the other, and as a source of energy the alcohol is equal to the isodynamic amount of the carbohydrates or fats which it replaces. If the gain of material is less or the loss more, or if the total energy metabolized is larger with the alcohol, the latter is inferior as a source of energy, and vice versa.

Experimental results.—Table 17 shows the differences between the available energy of the food in experiments with and without alcohol and the corresponding differences between the energy of body material gained or lost in the same experiments. The figures in the fourth and sixth columns are computed from those in the third and fifth, respectively, using the factor 5.65 for the energy of one gram of protein, and 9.54 for that of one gram of fat.

TABLE 17.—*Comparison of gains and losses of body protein and fat, and transformation of energy in experiments with and without alcohol.*

[Quantities per day.]

Groups, kind, and number of experiments.	Available in food.		Gain (+) or loss (−) in body material.				(g)
	(a) Protein.	(b) Energy.	(c) Protein.	(d) Energy of protein. $c \times 5.65$	(e) Fat.	(f) Energy of fat. $e \times 9.54$	Energy of material oxidized. $b-(d+f)$.
	Grams.	*Calories.*	*Grams.*	*Calories.*	*Grams.*	*Calories.*	*Calories.*
I. More directly comparable:							
9 experiments without alcohol	103	2, 917	− 3.5	−19	+ 1.1	+ 11	2, 925
6 experiments with alcohol	104	2, 925	− 6.9	−39	+ 2.4	+ 23	2, 941
Increase (+) or decrease (−) with alcohol	**+1**	**+ 8**	**− 3.4**	**−20**	**+ 1.3**	**+ 12**	**+16**
II. Less directly comparable:							
4 experiments without alcohol	100	2, 239	− 7.3	−41	− 2.3	− 22	2, 302
7 experiments with alcohol	98	2, 400	− 3.0	−17	+ 6.5	+ 61	2, 356
Increase (+) or decrease (−) with alcohol	**−2**	**+161**	**+ 4.3**	**+24**	**+ 8.8**	**+ 83**	**+54**
III. Average of I and II:							
13 experiments without alcohol	102	2, 691	− 4.8	−25	− .1	− 1	2, 717
13 experiments with alcohol	102	2, 750	− 7.1	−40	+ 3.8	+ 36	2, 746
Increase (+) or decrease (−) with alcohol	**0**	**+ 59**	**− 2.3**	**−15**	**+ 3.9**	**+ 37**	**+33**
Work and rest experiments of Group I:							
Work experiments compared—							
5 experiments without alcohol	100	3, 337	− 5.1	−27	−31.5	−301	3, 660
3 experiments with alcohol	100	3, 361	−10.0	−56	−29.2	−278	3, 690
Increase (+) or decrease (−) with alcohol	**0**	**+ 24**	**− 4.9**	**−29**	**+ 2.3**	**+ 23**	**+30**
Rest experiments compared—							
4 experiments without alcohol	106	2, 496	− 2.0	−11	+33.7	+317	2, 190
3 experiments with alcohol	108	2, 489	− 3.8	−21	+34.1	+319	2, 191
Increase (+) or decrease (−) with alcohol	**+2**	**− 7**	**− 1.8**	**− 10**	**+ .4**	**+ 2**	**+ 1**

The bold-face figures in the last line of each group in the columns for protein and fat give the gain or loss of material and energy in the alcohol experiments as compared with those without alcohol. The plus sign indicates greater gain and the minus sign greater loss with the alcohol than without it.

So far as the available (digestible) nutrients of the food are concerned, the quantities of protein are about the same and the quantities of energy slightly larger with alcohol than without it. but with the body material, on the other hand, there was generally a little larger loss of protein and a little larger gain or smaller loss of fat in the experiments with alcohol.

The figures in the last column represent the energy of material actually oxidized; that is, the total energy metabolized in the two classes of experiments. The full-face figures show by the + sign the excess of energy metabolized with the alcohol diet. The values are found by deducting the algebraic sum of the calories of energy gained or lost in protein and fat from the total available energy of the food as indicated by the letters and formulæ in the column headings. Thus in the first group we have an excess of $+8-(-20+12)=16$ calories of total energy metabolized in the alcohol as compared with the nonalcohol experiments. The same result is found by comparing the total quantities of energy metabolized, namely, 2,925 without and 2,941 with alcohol. The variations in the amounts of body material gained or lost and in the amounts of energy metabolized in the two classes of experiments may be due to either of three causes:

1. Such experimental errors as irregularities in the daily absorption of the food from the alimentary canal, or variations in the amounts of carbohydrates in the body which are here assumed to be constant from morning to morning, or from experiment to experiment, or small errors in the estimates of gains or losses of protein and fat from the gains or losses of nitrogen

and carbon. These errors are hardly avoidable, but on the whole they appear to counterbalance one another so that their effect is eliminated in the averages of a considerable number of experiments.

2. Differences in the activity of the subjects in the two classes of experiments. These differences are not easy to avoid. The man in the chamber may make more muscular effort on one day than on another in taking down his bed in the morning and in setting it up at night, or he may move about more in caring for the food and excretory products and weighing himself and t e absorbers. In the work experiments there may be differences in the external muscular work despite the best efforts to make the amounts constant from day to day. These differences in muscular activity, though small, may affect the metabolism of matter and energy.

3. The energy furnished by the alcohol may not be as efficient, calorie for calorie, in meeting the demands of the body as the energy from the materials which it replaces. It is hardly to be supposed that the experimental errors in categories (1) and (2) will be considerable. It is still less probable that they will be so concentrated in either the alcohol or nonalcohol experiments as to materially affect the average results. If, therefore, the differences between the figures for the experiments of the two classes are large and reasonably constant, it would seem fair to attribute them to differences in the actual value of the alcohol as compared with isodynamic amounts of fats and carbohydrates.

The figures of Table 17 show differences to the disadvantage of the alcohol. The differences are, however, mainly within the range of experimental error.[a]

In the more directly comparable experiments (Group I) the conditions with and without alcohol were closely similar. In Group II there were not inconsiderable differences between the amounts of protein and energy in the diet, in the number of subjects, in the number of experiments, and in the amounts of muscular exercise. These differences do not, in our judgment, destroy the value of the comparisons in Group II, though they do make the differences in result less decisive. The results of Group II are, therefore, valuable as confirming those of Group I.

Gains and losses of body material as indicative of the relative effectiveness of alcohol.—The differences in the gains or losses of protein and fat in the experiments with alcohol as compared with the others are slightly to the disadvantage of the alcohol. They thus imply that, calorie for calorie, the energy furnished to the body by the alcohol was less effective than that furnished by the carbohydrates and fats. These differences may be due to experimental errors, but even if they are wholly charged to the alcohol they make it only slightly inferior to the nutrients which it replaces. The inferiority is found only in the work experiments; in the rest experiments there is practically no difference between the alcohol and the ordinary nutrients in effectiveness.

Amounts of energy metabolized as indicative of the relative effectiveness of alcohol.—The results here are similar to those found in the comparison of gains or losses of material. This is to be expected, since the two measures are really different expressions of the same fundamental fact. In the rest experiments the results with and without alcohol are practically identical. The inferiority of the alcohol is limited to the work experiments.

Energy of material metabolized in work experiments with and without alcohol.—In the work experiments more material was oxidized than the food supplied, and the deficiency was made up by drafts upon the previously accumulated store of body protein and fat. Under these circumstances the body may be supposed to use the energy economically so as to make the drafts upon

[a] The differences between the results with and without alcohol are in all cases small. Considering them from the ordinary mathematical standpoint, they are, of course, noticeable; but in such physiological experimenting as this the unavoidable errors of individual experiments are considerable, and it is only when a large number of such experiments are averaged that differences of one or two parts in one hundred could properly be regarded as significant. Indeed, in this whole discussion there is danger of being misled by the figures in the tables unless one constantly recalls the fact that the range of unavoidable variation is wide. When, however, the averages of large numbers of experiments show a constant difference on one side or the other, it may be permissible to use such differences for conclusions and generalizations. On the whole, it might seem that in these experiments the results were sufficiently numerous to imply a slight inferiority of the alcohol in respect to the economy of the use of energy; but this inference rests upon the rather questionable assumption of the absolute equality of all conditions other than the presence or absence of alcohol in the diet.

its capital as small as practicable. It would therefore seem that the amounts of material oxidized in the experiments with the two kinds of diet would give a somewhat critical test of the power of the body to utilize the energy of alcohol, either directly for muscular work or indirectly to save the energy of other materials for that work. We may, then, determine the relative efficiency of the alcohol in supplying energy in these experiments by comparing the amounts of energy in material oxidized. If the amounts are the same with and without alcohol the inference is that the energy of the alcohol was utilized as effectively, so far as simply the economy of energy is concerned, as that of the fats and carbohydrates; but if more energy is metabolized with the alcohol we must conclude that it is inferior as a source of energy in a diet for muscular work. We may take, for instance, the pair of experiments Nos. 11 and 12, in which the man was at hard work. (See Table CXX, p. 390.) His body used, in No. 11, with ordinary diet, 3,901 calories of energy per day. The food digested and absorbed from the diet supplied 3,510 calories, and the body burned enough of its previously accumulated material, protein and fat, to supply the lacking 391 calories.

In the corresponding alcohol experiment, No. 12, enough of the fats, sugar, and starch of the previous diet to furnish about 500 calories of energy was taken out and replaced by sufficient alcohol to furnish approximately the same amount, 500 calories. It happened that the total energy in the alcohol ration was about 30 calories the larger. Furthermore, the availability of the food proved to be slightly larger, so that the whole available energy of the alcohol ration was 3,614 calories. The amount of work done and the other conditions were practically the same as in the previous experiment. The body transformed 3,922 calories and in order to do so drew enough from its own store to furnish 308 calories.

According to these figures the body burned a trifle more material in the alcohol experiments than in the others—enough to furnish 3,922 instead of 3,901 calories of energy. But the alcohol diet furnished, with the alcohol, a somewhat larger amount of total energy, and furthermore a somewhat larger proportion of the nutrients of the ordinary food was digested, so that the body had 104 calories more of available energy. The fact that it drew 83 calories less from its previously stored material in this experiment than in No. 11 indicates that it used its energy economically. In each of these two cases the daily amount of external muscular work measured was equivalent to not far from 200 calories. In the first experiment all of this came from ordinary food. It may be that in the second experiment likewise it all came from the reduced supply of the ordinary food, and that none of the energy actually transformed into muscular work came from the alcohol. There is, however, no reason to suppose that the body made any distinction between the energy from the alcohol and that from the other fuel, and even if it did so it made just as good use of the energy of the alcohol to meet its other needs as it did of the energy of the ordinary nutrients.

The test of the comparative economy of the two diets so far as concerns the supply of energy is found in the amount of energy of material oxidized. This was 20 calories, or about 0.6 per cent the larger in the alcohol diet. This is far inside the limit of experimental error. Indeed, the quantity of energy given off from the body as measured by the respiration calorimeter was 5 calories larger with the ordinary than with the alcohol diet. (See Table CXX of the Appendix.) Of course such differences have practically no significance in physiological experimenting.

The results of the experiments in their bearing upon the subject are summarized herewith:

Average amounts of energy in material oxidized.

[Calories per day.]

Groups.		Experiments.	Ordinary diet.	Alcohol diet.
I	A–C..	More directly comparable, rest	2,190	2,191
I	D–F..	More directly comparable, work	3,664	3,694
I	A–F..	More directly comparable, all	2,927	2,942
II	G–I..	Less directly comparable, rest	2,302	2,356
III	A–I..	All above	2,719	2,747

It appears that in the more directly comparable experiments the energy of material oxidized averaged the same where the subjects were at rest, but was about 1 per cent larger with the alcohol when they were at work. In the less directly comparable experiments, in all of which the subjects were at rest, the average was larger by about 2 per cent with the alcohol diet. This is perhaps no more than was to be expected with the slight differences in the conditions of the experiments.

In this method of comparison by amounts of material and energy oxidized, as in the previous method, the differences were too small to be taken into account in individual experiments, but appearing as they do in the average of a number of experiments they are not without significance. The conclusion is that the energy of the alcohol diet was slightly less economically used than that of the ordinary diet, especially in the work experiments. This implies that the energy of the alcohol itself was less economically utilized than that of the fats and carbohydrates, but the differences are so small as to be of little or no practical consequence.

Relative effectiveness of alcohol expressed in percentages.—In the work experiments of Group I 3,664 calories were metabolized with the ordinary, and 3,694 with the alcohol ration. The relative costs of maintaining the body with the two rations were thus 3,664 : 3,694 = 100 : 100.8 or 99.2 : 100; the difference of 30 calories being 0.8 per cent. Assuming the difference to be due wholly to the inferiority of the alcohol ration, its effectiveness, calorie for calorie, would be 99.2 per cent of that of the ordinary ration, so far as the energy is concerned.

The alcohol supplied 500 calories of energy, of which the 30 calories would represent 6 per cent. If we charge the deficit wholly to the alcohol, the latter would be, calorie for calorie, 6 per cent less effective than the fats and carbohydrates it replaced. In other words, the effectiveness of the alcohol as a source of energy in the ration for muscular work in this case would be 94 per cent of that of the isodynamic amounts of carbohydrates and fats.

Calculated in these ways the effectiveness of the alcohol ration as compared with the ordinary ration, and that of the alcohol as compared with carbohydrates and fats in the experiments of Groups I–III, would be as follows:

Percentages of effectiveness of energy.

Experiments. Groups.	Experiments. Classification.	Energy of alcohol ration as compared with energy of ordinary ration.	Energy of alcohol as compared with energy of carbohydrates and fats.
		Per cent.	*Per cent.*
I	More directly comparable	99.5	97.0
II	Less directly comparable	97.7	89.2
III	Average of I and II	99.0	94.4
I	Rest experiments	100.0	99.8
I	Work experiments	99.2	94.0

Summary.—The conditions and results of these experiments and the inferences here drawn from them regarding alcohol as a source of muscular energy may be briefly summarized:

1. We have here experiments with ordinary diet compared with other experiments in which the conditions were similar except that carbohydrates and fats sufficient to supply 500 calories of energy of the 2,200–3,600 calories in the daily ration were replaced by the isodynamic amount (about 72 grams) of alcohol, the latter being taken in six doses. The conditions of work and rest were very nearly the same in the corresponding experiments, with and without alcohol.

2. The amounts of material and energy transformed in the experiments with alcohol were very nearly the same as in the corresponding ones without alcohol. Where the ration was insufficient to meet the needs of the body, and it had to draw upon its store of fat and protein to supply the lacking energy, the drafts were practically the same with the ordinary as with the alcohol diet, so far as concerns the energy of the body material drawn upon.

3. The utilization of the energy of the whole ration was slightly less economical with the alcohol than with the ordinary diet, especially when the subjects were at hard muscular work.

but the difference in favor of the ordinary food was very small indeed, hardly enough to be of practical consequence. From this it follows that the energy of the alcohol was utilized very nearly or quite as well as that of the other fuel ingredients which it replaced.

4. That the alcohol contributed its share of energy for muscular work is a natural hypothesis and very probable, but not absolutely proven. The hypothesis that the energy of the alcohol was not so used, is not called for as an explanation of any fact observed in these experiments.

It should not be forgotten that the desirability of alcohol as part of a diet for muscular work is not decided by the narrower questions here discussed. There is a very essential difference between the transformation of the potential energy of alcohol into the mechanical energy of muscular work and the advantage or disadvantage of alcohol in the diet of people engaged in muscular labor. Even with the small doses in these experiments there were indications that the subjects worked to slightly better advantage with the ordinary rations than with the alcohol. The results of practical tests on a large scale elsewhere coincide with those of general observation in implying that the use of any considerable quantity of alcoholic beverages as part of the diet for muscular labor is generally of doubtful value and often positively injurious.[a] Aside from the question of the power of alcohol to protect protein and fat and supply energy to the body for various useful purposes, there are the far weightier considerations of the general effect of alcohol upon the muscular and especially the nervous system and upon health and welfare. Upon these most serious hygienic, economical, and ethical problems the experiments here reported throw no special light.

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[a] For a summary of results of experiments upon various phases of this subject by different investigators, see article by Prof. J. H. Abel in the Report of the Physiological Subcommittee of the Committee of Fifty for the Investigation of the Drink Problem. (See page 261 of this memoir.)

SUMMARY OF PLAN AND RESULTS OF THE EXPERIMENTS.

Purpose, subjects, and method.—The purpose of the experiments, so far as the physiological action of alcohol is concerned, was primarily to get light upon the ways by which its potential energy is transformed and utilized in the body, but attention was also given to the effects of alcohol upon the digestion of the food taken with it, the proportions of alcohol that were oxidized and escaped oxidation, and its effects upon the metabolism of carbon and nitrogen and the gain and loss of fat and protein in the body.

The subjects were three young, healthy, active men who were ordinarily engaged in rather light work; one was a laboratory assistant, one a physicist, and one a chemist in the chemical laboratory of Wesleyan University, where the experiments were made. The first, E. O., a Swede by birth, had been accustomed from his youth to drink small quantities of alcoholic beverages; the other two, A. W. S. and J. F. S., had always been abstainers.

The results of experiments with ordinary diet were compared with those of experiments in which part of the fats and carbohydrates of the ordinary food were replaced by the isodynamic amount, about 72 grams ($2\frac{1}{2}$ ounces) of absolute alcohol, generally in the form of commercial alcohol, though in one experiment brandy and in another whisky was used. The amount of alcohol was about as much as would be supplied in a bottle of claret, or 6 ounces of whisky, or 5 ounces of brandy.

The ordinary diet consisted of meat, milk, bread, cereals, butter, sugar, and the like, with, in some cases, coffee. The quantities were such as had been found to be sufficient, or nearly so, for meeting the demands of the body under the conditions of the experiments, whether of rest or muscular work. The methods of preparation were such as to make the food palatable to the subject.

During the metabolism experiments proper the subjects were in the chamber of the respiration calorimeter, where they remained during periods varying from 4 to 9 days. The sojourn was made comfortable and the conditions seemed to be normal. Each metabolism experiment or series of experiments in the respiration chamber was preceded by a period during which the subject had essentially the same diet and nearly the same amount of muscular exercise outside the chamber. In these preliminary experiments the amounts, composition, and heats of combustion of the food, feces, and urine were determined. In the metabolism experiments the determinations include besides these the water and carbon dioxide of the incoming and outgoing air current by which the chamber was ventilated, the heat given off from the body, and, in the work experiments, the heat equivalent of the muscular work done. In the alcohol experiments the determinations were made of the small amounts of alcohol excreted by the kidneys, lungs, and skin.

Accordingly the data of the metabolism experiments show the income and outgo of the body as expressed in terms of (a) nitrogen, carbon, and hydrogen; (b) water, protein, fats, carbohydrates, and mineral matters; (c) potential energy of food and unoxidized excreta, and (d) kinetic energy of heat given off from the body and external muscular work performed. The accuracy of the apparatus and method were assured by burning alcohol within the chamber measuring the amounts of carbon dioxide, water, and heat produced. Such tests were made generally between each two experiments or experimental series. Taking the theoretical amounts at 100, the average amounts found were carbon dioxid, 99.6; water, 100.6; heat, 99.9.

In the so-called "rest" experiments the subject had no more muscular exercise than was involved in dressing and undressing, weighing himself, arranging his folding bed, chair, and table.

and caring for the food and solid and liquid excreta. His diversion was found in reading, writing, and occasional conversation by telephone with persons outside. In the "work" experiments the subject engaged in the active muscular exercise of riding a stationary bicycle for eight hours or thereabouts per day. The wheel of the bicycle was belted to a dynamo connected with an electric lamp, so that the muscular power which was applied to the pedals was converted partly into heat by friction but mainly into electrical energy and then into heat. The apparatus was calibrated so as to serve as an ergometer for measuring the external muscular work.

In interpreting the results in their bearing upon the physiological action of alcohol, it should be particularly noted that the whole amount of alcohol ingested per day was small and that furthermore it was taken in 6 doses, 3 with meals and 3 between meals. The object of the experiments was to study the action of alcohol under conditions calculated to secure the minimum of influence upon the nervous system. With such small doses, the equivalent of a glass of wine each, and thus distributed, two of the subjects were able to detect practically no sensible effect of the alcohol, while the third, J. F. S., felt nothing more than at times a slight "tingling" in the ears. There was in some cases an apparent though slight quickening of pulse rate, but practically no lowering of body temperature was observed. In such freedom from nervous disturbance it was believed that the normal nutritive action would be best observed.

There is the more reason for emphasizing this last point, because in the majority of the published experiments with men and animals for the study of the effects of alcohol the quantities of the latter have been much larger. Doses of 1 to 1½ grams per kilogram of body have commonly been considered small, and those of 2 to 3 grams per kilogram have been common and generally taken on an empty stomach. Often the amounts have been such as to cause the symptoms of drunkenness. In our experiments, on the other hand, the whole amount per day was only about 1 gram per kilogram body weight; the individual doses were only about one-sixth of a gram per kilogram, and half of them were taken with meals. This fact doubtless accounts for a not inconsiderable share of the difference between the results of our experiments and those found by a number of other investigators.

While the quantities of alcohol were small, the energy sufficed to make about one-fifth of the total energy of the diet in the "rest," and one-seventh of the total energy of the diet in the "work" experiments.

It is to be especially noted that these experiments were not made to test the effects of alcohol upon muscular or nervous activity or power, nor do they lead to any conclusions regarding the effects of alcohol when taken habitually or in large quantities.

The observed results.—The results, as shown by the statistics of the experiments, may be briefly stated as follows:

1. The quantities of alcohol eliminated by the lungs, skin, and kidneys varied from 0.7 to 2.7 grams, and averaged 1.3 grams per day (see p. 258). This corresponds to an average of 1.9 per cent of the whole alcohol ingested. Accordingly over 98 per cent of the ingested alcohol was oxidized in the body. There is, however, reason to believe that 99 per cent would more nearly represent the proportion actually oxidized.

2. The experiments give data for comparing the availability and fuel value of alcohol with those of the nutrients of ordinary food. The word "availability" as here applied to the ordinary nutrients, expresses the proportion which is digested and made available for the building and repair of tissue and the yielding of energy. This proportion is the difference between the total amount and that excreted by the intestine. In like manner the available alcohol would be the difference between the total amount ingested and the amount excreted by the lungs, skin, and kidneys, practically none being excreted by the intestine. The available energy of the ordinary nutrients is the total energy (heat of oxidation) less that of the material unoxidized. For fats, carbohydrates, and alcohol it is the heat of oxidation of the total available material. For the protein it is the same, less the heat of oxidation of the unoxidized residue excreted by the kidneys. The available energy is taken as the measure of the fuel value. The following table compares the coefficients of availability and the fuel values of the protein, fats, and carbohydrates of ordinary

diet, as found by a considerable number of experiments,[a] with those of the alcohol as shown by the experiments here reported.

TABLE 18.—*Comparison of availability (digestibility) and fuel values of nutrients of food in ordinary diet with those of alcohol.*

	Heat of combustion per gram.	Coefficients of availability—		Fuel values.			
		Of material.	Of energy.	Referred to available material.		Referred to total material.	
				Per gram.	Per pound.	Per gram.	Per pound.
	Calories.	*Per cent.*	*Per cent.*	*Calories.*	*Calories.*	*Calories.*	*Calories.*
Protein	5.65	92	70	4.4	2,000	4.0	1,820
Fats	9.40	95	95	9.4	4,260	8.9	4,040
Carbohydrates	4.10	97	97	4.1	1,860	4.0	1,820
Alcohol	7.07	98	98	7.1	3,210	6.9	3,140

The isodynamic values of alcohol, carbohydrates, and fats are thus in the ratios of 6.9 : 4 : 8.9, and 1 gram of alcohol would be isodynamic with 1.73 grams carbohydrate or 0.78 gram of fats of ordinary food materials.

3. The proportions of food and of the several kinds of nutrients digested and made available for use in the body were practically the same in the experiments with and those without alcohol in the diet. The only difference worthy of mention was in the proportions of protein made available. These were very slightly larger with the alcohol, but the difference was too small to be of practical consequence. In all the experiments, both those with and those without alcohol, the results agree very closely with those commonly found in digestion of food in ordinary mixed diet by healthy men.

4. The potential energy of the alcohol was transformed into kinetic energy in the body as completely as that of the ordinary nutrients. The income and outgo of energy were equal in the experiments without alcohol; the same was true in the experiments with alcohol. In all the experiments the body obeyed the law of conservation of energy.

5. With the exception of the energy of the external muscular work in the work experiments, all of the energy of the food, including that of the alcohol, left the body as heat, and must therefore have been transformed into heat within the body. Part of this total energy must have been used for the internal mechanical (muscular) work; the energy thus used was therefore transformed into heat before leaving the body.

6. The radiation of heat from the body was very slightly greater with the alcohol diet than with the ordinary diet, but the difference was extremely small—enough to make only about 1 per cent of the whole energy metabolized and not over 6 per cent of the energy of the alcohol.

7. The efficiency of alcohol in the protection of body fat from consumption was very evident. The losses of fat were no larger and the gains no smaller with the alcohol diet than with the corresponding diet without alcohol. In this respect there was no indication of any considerable difference between the alcohol and the nearly isodynamic amounts of fats and carbohydrates which it replaced. This was the case in all the experiments.

8. The efficiency of the alcohol in protecting body protein was evident, but it was not fully equal in this respect to the isodynamic amounts of the ordinary nutrients. The results, however, were not the same with the different subjects. With E. O., who had been accustomed to use alcoholic beverages, the differences between the alcohol diet and the ordinary diet in their apparent effects upon nitrogen metabolism were small. The figures showed a slightly larger output of nitrogen with the alcohol, but the differences were not large enough to be of especial significance. With A. W. S., who was unaccustomed to alcohol, its use in the place of other

[a] See discussion of this subject by W. O. ATWATER and A. P. BRYANT in the Report of the Storrs (Conn.) Experiment Station for 1899, from which the figures for ordinary nutrients in the table are taken.

nutrients resulted, at first, in an increased excretion of nitrogen in the urine and inferentially a greater catabolism of protein, but after 5 or 6 days the output of nitrogen fell to what seemed to be the amount with ordinary diet, and when the alcohol was removed and diet thus reduced there was an increase in the output. These results implied that the alcohol at first failed to protect protein but was afterwards able to do so. There was, however, but one series of experiments with this subject. With J. F. S., also an abstainer, the alcohol periods covered only 3 days, during which there was in each case an increased nitrogen catabolism. On the whole these experiments accord with the belief that with some persons, especially those who are not accustomed to the use of alcohol, it may fail to protect protein; but this action is temporary and the more permanent influence is to protect protein.

9. That a part of the potential energy of the alcohol was transformed into the kinetic energy of muscular work these experiments do not prove, though they make it highly probable. They imply that, so far as the utilization of the total energy of the diet was concerned, there was a slight advantage in economy in favor of the ordinary as compared with the alcohol diet, especially when the subjects were at hard muscular work, but the difference was inside the limits of experimental error and too small to be of practical consequence. On the average it was less than 1 per cent of the total energy and hardly reached 5 per cent of the energy of the alcohol. From this it follows that the energy of the alcohol was utilized nearly if not quite as well as that of the fats, sugar, and starch which it replaced.

10. We repeat that there is a very essential difference between the transformation of the potential energy of alcohol into the kinetic energy of heat, or of either internal or external muscular work, and the usefulness or harmfulness of alcohol as a part of ordinary diet. Regarding this latter question the experiments bring no more evidence than they do regarding the influence of alcohol upon the nervous system or its general effect upon health and welfare.

APPENDIX.

The details of the experiments described above are set forth in the following pages, and include:

1. Kinds of experimental data and methods for obtaining them.
2. Statistical details of metabolism experiments with alcohol.
3. Statistical details of digestion experiments with alcohol.
4. Tabular summaries.

A list of the experiments, with groupings for comparison, may be found in Table 1, on page 241 of the first part of this report. As there explained, the metabolism experiments here described in detail were made with alcohol as a part of the diet. They are compared with similar experiments without alcohol, which have been described in detail elsewhere. Each metabolism experiment or series of metabolism experiments with or without alcohol not only included a digestion experiment, but was also preceded by such an experiment. The data of these digestion experiments are also given beyond. The experiments without alcohol and two of those with alcohol have been described in detail elsewhere. In several instances the results are here summarized with the details of the alcohol experiments.

DATA.—EXPERIMENTAL METHODS.

METABOLISM EXPERIMENTS.

The larger part of the statistics of the metabolism experiments have to do with the income and outgo of material and energy.

Experimental data of income.—These include statistics of the kinds, amounts, composition, and potential energy of food and drink, the volume of the ventilating current of air entering the chamber and the amount of carbon dioxide and water in that air. The food for each experiment was selected before the experiment began and the desired amounts for different meals were placed in suitable jars, as described on page 239. Such of the analytical determinations as were necessary for the control of the diet, in order to insure the desired amount of protein and energy, were made previous to the beginning of the experiment.

Experimental data of outgo.—These include statistics of the amount, composition, and heat of combustion of the unoxidized materials of feces and urine, the quantity of carbon dioxid and water in the air leaving the chamber, and the total energy given off by the body in the form of heat and external muscular work.

Apparatus and general methods of inquiry.—The respiration calorimeter and method of its use have been described in detail in publications referred to on page 236.[a] The methods of analysis of food, feces, and urine were, in the main, those adopted by the Association of Official Agricultural Chemists,[b] but with certain modifications which have been developed in this laboratory.[c] The heats of combustion were determined by use of the bomb calorimeter.[d]

[a] Bulletins 44, 63, 69, and 109 of the Office of Experiment Stations of the U. S. Dept. Agr.

[b] See Bulletin 46, revised, of the Division of Chemistry, U. S. Dept. Agr.

[c] See U. S. Dept. Agr., Office of Experiment Stations, Bul. 44, p. 22; Bul. 69, p. 18, and Report of Storrs (Conn.) Expt. Sta., 1891, p. 47. The methods for the determination of carbon and hydrogen in use in this laboratory are described in detail by F. G. Benedict in Elementary Organic Analysis, The Chemical Publishing Co., on page 51 of which the apparatus is pictured.

[d] The bomb calorimeter and accessory apparatus used have been described by W. O. Atwater and associates in Bulletin 21 of the Office of Experiment Stations of the U. S. Dept. Agr., p. 123, and in the Reports of the Storrs (Conn.) Expt. Sta., 1894, p. 133, and 1897, p. 199.

Further descriptions of experimental methods are given in connection with the descriptions of experiment 12, beyond.

Composition of food materials and feces.—The figures for the analyses of the food materials and feces of the alcoholic experiments here described are given in Tables I and II.

TABLE I.—*Composition of food materials used in metabolism experiments Nos. 12, 15, 16, 17, 18, 19, 20, 22, 27, 30, and 33.*

Laboratory No.	Food material.	Experiment No.	Nitrogen.	Carbon.	Hydrogen.	Water.	Protein (N × 6.25).	Fat.	Carbohydrates.	Ash.	Heat of combustion per gram determined.
			Per ct.	Per ct.	Per ct.	Per ct.	Per ct.	Per ct.	Per ct.	Per ct.	Calories.
2860	Beef cooked	12	4.38	17.85	2.61	65.3	27.4	5.6	....	2.5	2.000
3009	.....do	15–17	4.17	15.24	2.29	69.2	26.1	2.6	....	2.2	1.682
3022	.....do	18–20	4.46	16.57	2.54	66.7	27.9	2.6	....	2.1	1.827
3027	.....do	22	5.59	23.57	3.37	56.6	34.9	6.1	....	1.0	2.633
3176	.....do	27	5.41	19.55	2.70	62.5	33.8	2.8	....	.9	2.198
3186	.....do	30	5.72	20.89	2.99	60.3	35.7	3.0	....	1.0	2.327
3205	.....do	33	5.13	18.55	2.66	64.5	32.1	2.8	....	1.0	2.075
2858	Ham, deviled	12	2.93	36.10	5.45	41.4	18.3	36.4	....	4.0	4.366
2861	Butter	12	.08	63.81	10.14	10.9	.5	86.4	....	2.2	7.906
3003	.....do	15–17	.19	61.90	10.40	10.3	1.2	86.0	....	2.5	7.959
3021	.....do	18–20	.21	66.23	10.55	8.7	1.3	87.5	....	2.5	8.178
3029	.....do	22	.17	69.16	10.52	9.5	1.1	86.8	....	2.6	8.027
3177	.....do	27	.26	65.02	10.02	9.9	1.6	85.9	....	2.6	8.002
3187	.....do	30	.20	65.11	10.44	9.2	1.3	86.3	....	3.2	8.048
3206	.....do	33	.20	65.58	10.37	8.4	1.3	87.6	....	2.7	8.210
2857	Milk, whole	12	.49	6.57	1.00	87.5	3.1	4.5	4.2	.7	.798
3024	.....do	18–20	.51	7.03	.94	86.6	3.2	4.4	5.0	.8	.782
3190	.....do	30	.64	8.00	1.20	85.0	4.0	5.4	4.8	.8	.900
3201	.....do	33	.66	8.22	1.24	85.1	4.1	5.2	4.8	.8	.904
3006	Milk, skimmed	15–17	.65	4.61	.66	89.5	4.1	.1	5.5	.8	.468
3031	.....do	22	.58	4.11	.59	90.7	3.6	.1	4.8	.8	.409
3179	.....do	27	.67	4.63	.63	90.0	4.2	.3	4.7	.8	.462
2842	Maize breakfast food	12	1.88	44.39	6.49	4.9	11.8	8.2	73.4	1.7	4.437
3004	Cereal, parched	15–22	1.82	41.39	6.17	6.1	11.4	.6	80.4	1.5	4.056
3168	.....do	27	1.87	42.20	5.94	5.6	11.7	1.7	79.1	1.9	4.136
3193	.....do	30–33	1.92	42.72	6.30	4.1	12.0	1.4	80.5	2.0	4.202
2859	Bread	12	1.51	27.27	3.92	40.4	9.4	1.0	48.1	1.1	2.663
2968	.....do	15–20	1.27	27.33	4.11	41.7	7.9	2.8	46.3	1.3	2.710
3032	.....do	22	1.27	28.05	3.98	40.4	7.9	3.4	47.0	1.3	2.889
3180	.....do	27	1.42	27.76	3.99	39.3	8.9	1.6	48.9	1.3	2.803
3192	.....do	30	1.50	29.14	4.30	36.5	9.4	2.0	50.8	1.3	2.931
3204	.....do	33	1.38	28.27	4.30	37.8	8.6	2.5	49.8	1.3	2.869
3181	Gingersnaps	27, 30	1.00	44.32	6.61	4.1	6.2	8.3	79.8	1.6	4.434
3207	.....do	33	.88	43.87	7.20	3.7	5.5	7.2	81.6	2.0	4.434
3069	Horse-radish	17	.20	4.50	.60	89.3	1.3	.2	8.3	.9	.380
	Sugar	([a])	......	42.10	6.48	......	......	......	100.0	......	3.960
	Alcohol	([b])	......	52.17	13.05	......	......	......	....	......	7.069

[a] Used in all the experiments. [b] As pure ethyl alcohol.

TABLE II.—*Composition of feces in metabolism experiments Nos. 12, 15, 16, 17, 18, 19, 20, 22, 27, 30, and 33.*

Laboratory No.		Experiment No.	Nitrogen.	Carbon.	Hydrogen.	Water.	Protein (N × 6.25).	Fat.	Carbohydrates.	Ash.	Heat of combustion per gram determined.
			Per ct.	Per ct.	Per ct.	Per ct.	Per ct.	Per ct.	Per ct.	Per ct.	Calories.
2863	Feces	12	1.35	13.05	1.85	74.1	8.4	7.0	6.1	4.4	1.473
3008	.....do	15–17	1.57	14.85	2.07	68.3	9.8	5.6	8.6	7.7	1.675
3033	.....do	18–20	1.62	14.03	1.94	72.6	10.1	6.3	6.3	4.7	1.571
3035	.....do	22	1.59	14.44	2.07	69.3	9.9	5.2	8.5	7.1	1.610
3184	.....do	27	1.53	12.26	1.10	69.5	9.6	2.9	9.7	8.3	1.335
3196	.....do	30	1.43	13.53	1.89	71.2	8.9	4.5	9.8	5.6	1.487
3210	.....do	33	1.37	13.22	1.92	71.0	8.5	5.0	9.4	6.1	1.452

TABLE III.—*Composition of materials not included in Tables I and II used in connection with digestion experiments.*

Laboratory No.	Material.	Digestion experiment No.	Nitrogen.	Water.	Protein.	Fat.	Carbohydrates.	Ash.	Heat of combustion per gram. (determined.)
			Per cent.	*Per cent.*	*Per cent.*	*Per cent.*	*Per cent.*	*Per cent.*	*Calories.*
2845	Milk	47	0.50	90.48	3.13	0.10	5.52	0.77	402
2846	....do	48	.53	90.36	3.31	.11	5.45	.77	414
2856	....do	51	.53	85.88	3.31	5.00	5.07	.74	865
3005	....do	80	.64	80.44	3.98	.06	5.66	.86	467
2809	Feces	41	1.89	71.44	11.79	5.38	6.63	4.76	1,564
2810	....do	42	1.81	70.96	11.30	4.95	7.63	5.16	1,530
2847	....do	47	1.48	73.37	9.28	3.84	9.08	4.43	1,349
2848	....do	48	1.57	71.01	9.83	4.15	10.21	4.80	1,445
2862	....do	51	1.47	70.32	9.20	7.56	7.42	5.50	1,598
3007	....do	80	1.68	62.69	10.53	7.17	12.03	7.58	2,068
3034	....do	83	1.75	68.75	10.93	5.68	7.60	7.04	1,568

Composition of coffee infusion.—Coffee infusion was prepared by pouring boiling water over ground coffee and straining the infusion thus obtained. The nitrogen was determined in this infusion and found to amount to about 0.004 grams per liter—quantities too small to be taken into account. The coffee infusion is therefore reckoned simply as so much water.

STATISTICAL DETAILS OF METABOLISM EXPERIMENTS.

The details of the methods of conducting the experiments and of computing the results, as well as the statistical tables in which these results are presented, will be advantageously given in connection with the description of one of the experiments. For this purpose we select No. 12, which is the first in consecutive order of those here described in detail.

EXPERIMENT NO. 12—WORK WITH ALCOHOL DIET.

Subject.—E. O., laboratory assistant, 31 years of age and weighing, without clothing, about 71 kilograms (157 pounds).

Occupation during experiment.—Work 8 hours a day upon a stationary bicycle belted to a small dynamo, thus making an ergometer as described on page 237. The voltage was measured and the current passed through resistance within the apparatus and thus transformed into heat and measured with the heat given off by the subject. Previous calibration showed the amount of work done in driving the bicycle.

Duration.—Preliminary period 4 days, beginning with breakfast April 8, 1898, and experiment proper 4 days, beginning at 7 a. m. April 12 and ending at 7 a. m. April 16. The subject entered the respiration chamber on the evening of April 11 and thus spent 5 nights and 4 days within the calorimeter.

Diet.—Ordinary food furnishing 121 grams of protein and 3,379 calories of energy, and in addition 72.4 grams of alcohol furnishing 512 calories of energy, making the total energy of the diet 3,891 calories. The alcohol was added to a sweetened coffee infusion. It was taken in 6 doses, 3 with the meals and the other 3 between meals and just before retiring. The coffee infusion was prepared in the usual manner, care being taken to keep that given to the subject free from particles of coffee. To 690 grams of infusion were added 50 grams of sugar and 80 grams of commercial ethyl alcohol containing 90.63 per cent absolute alcohol. The 80 grams of commercial alcohol thus contained 72.4 grams of absolute alcohol and 7.5 grams water. The diet was practically the same during both the preliminary digestion experiment and the metabolism experiment proper. The kinds and amounts of different food materials taken at each meal and the amounts of coffee infusion and water consumed at different times during the day are shown herewith.

Diet in metabolism experiment No. 12.

FOOD.

	Breakfast.	Dinner.	Supper.	Total.
	Grams.	*Grams.*	*Grams.*	*Grams.*
Beef	75	100		175
Deviled ham			50	50
Butter	25	40	30	95
Whole milk	250	260	390	900
Bread	75	100	125	300
Maize breakfast food	60			60
Sugar	20		[a]50	[a]70
Alcohol				[b]72.4

DRINK.

Time.	Amount.	
	Coffee infusion with alcohol and sugar.[c]	Water.
	Grams.	*Grams.*
Breakfast	175	200
10.20 a. m	150	200
12.30 p. m		200
Dinner	175	
3.50 p. m	125	200
Supper	175	
10 p. m	130	200
Total	930	1,000

[a] Including 50 grams used in coffee infusion and alcohol.
[b] Added to coffee infusion and taken as indicated below.
[c] Made by adding 80 grams of 90.5 per cent commercial alcohol and 50 grams sugar to 800 grams coffee infusion. The mixture then contained 807.5 grams water, 72.4 grams absolute alcohol and 50 grams sugar.

Daily routine.—In order to make the conditions of the experiment on the different days as nearly uniform as practicable a daily programme was drawn up and one copy was given to the subject within the respiration chamber while others were posted outside for the use of those carrying on the details of the experiment. The routine in experiment No. 12 was as follows:

Daily program—Metabolism experiment No. 12.

7.00 a. m	Rise, pass urine, collect drip, weigh absorbers, weigh self stripped and dressed.
7.45 a. m	Breakfast, drink 200 grams water.
8.20 a. m	Begin work.
10.20 a. m	Rest 10 minutes, drink alcohol, drink 200 grams water.
10.30 a. m	Begin work.
12.30 p. m	Stop work, drink 200 grams water.
1.00 p. m	Pass urine, collect drip, weigh absorbers.
1.15 p. m	Dinner.
1.50 p. m	Begin work.
3.50 p. m	Stop work, rest 10 minutes, drink alcohol, drink 200 grams water.
4.00 p. m	Begin work.
6.00 p. m	Stop work.
6.30 p. m	Supper, change underclothes, weigh self stripped and dressed.
7.00 p. m	Pass urine, collect drip, weigh absorbers.
10.00 p. m	Take cover off food aperture, drink 200 grams water, retire.
1.00 a. m	Pass urine.

The subject weighed himself, with and without clothing, at about 7 a. m. and 7 p. m. each day of the experiment. He observed his pulse rate, after intervals of rest, and took his body temperature from time to time by means of a registered clinical thermometer. The body temperatures were measured *sub lingua*. We do not think that great reliance can be placed upon observations for either pulse rate or temperature when made by the subject upon himself under such conditions.

A hygrometer inside the chamber was observed two or three times each day in order to give data concerning the amount of water vapor within the calorimeter, but the figures are not used in the final computations of results.

These statistics noted by the subject within the calorimeter are recorded in a diary, together with any other information which he thinks may be of value in interpreting the results of the experiment.

The main facts in the diary of experiment No. 12 are shown in Table IV.

Table V recapitulates the record of work done on the ergometer. It is much less than would be required to propel a bicycle the number of miles indicated by the cyclometer.

TABLE IV.—*Summary of diary—Metabolism experiment No. 12.*

Date and time.	Weight of subject.		Pulse rate per minute.	Tempera-ture.	Hygrometer.	
	Without clothes.	With clothes.			Dry bulb.	Wet bulb.
	Kilograms.	*Kilograms.*		*°F.*	*°C.*	*°C.*
Apr. 12, 7.00 a. m	70.92	75.09	64	98.4	21.5	16.4
12, 12.40 p. m			68	98.8	21.8	18.6
12, 7.00 p. m	71.72	75.38				
12, 9.45 p. m			77	98.3	21.5	18.0
13, 7.00 a. m	71.09	74.82	56	96.1	21.4	17.4
13, 12.40 p. m			68	98.8	21.5	18.8
13, 6.30 p. m	71.40	74.96				
13, 9.45 p. m			71	98.4	21.5	18.0
14, 7.00 a. m	70.56	74.19	58	97.0	21.4	17.0
14, 12.40 p. m			70	99.0	21.4	18.8
14, 6.30 p. m	70.98	74.50				
14, 9.45 p. m			73	98.5	21.5	17.8
15, 7.00 a. m	70.47	73.98	57	97.2	21.3	16.8
15, 12.40 p. m			72	97.0	21.7	19.0
15, 7.00 p. m	71.12	74.51				
15, 9.45 p. m			74	99.0	21.5	17.8
16, 7.00 a. m	70.31	73.98	60	96.4	22.0	18.4

TABLE V.—*Record of work done—Metabolism experiment No. 12.*

Date and time.	Cyclometer reading.[a]	Number of miles.	Actual duration of work.	Rate.	Heat equivalent.
			Mins.	*Watts.*	*Calories.*
Apr. 12, 7.00 a. m	641				
		41	120		
12, 10.20 a. m	600			31	107.1
		41	120		
12, 12.30 p. m	559				
		38	120		
12, 3.50 p. m	521			28	96.7
		39	120		
12, 6.00 p. m	482				
13, 8.20 a. m	480				
		40	120		
13, 10.20 a. m	440			31	107.1
		40	120		
13, 12.30 p. m	400				
		41	120		
13, 3.50 p. m	359			30	103.7
		40	120		
13, 6.00 p. m	319				
14, 8.20 a. m	316				
		35	120		
14, 10.20 a. m	281			29	100.2
		39	120		
14, 12.30 p. m	242				
		36	120		
14, 3.50 p. m	206			27	93.2
		36	120		
14, 6.00 p. m	170				

[a] The cyclometer was reversed.

TABLE V.—*Record of work done—Metabolism experiment No. 12*—Continued.

Date and time.	Cyclometer reading.[a]	Number of miles.	Actual duration of work.	Rate.	Heat equivalent.
			Mins.	*Watts.*	*Calories.*
Apr. 15, 8.20 a. m	168				
		36	120		
15, 10.20 a. m	132			30	103.7
		39	120		
15, 12.30 p. m	93				
		36	120		
15, 3.50 p. m	57			26	89.3
		23	120		
15, 5.30 p. m	34				
	....	600	1,920	....	801.0

[a] The cyclometer was reversed.

Food and excreta.—The weight, composition, and heat of combustion of the food and feces in this experiment are shown in Tables VI and VII. The weights of the different elements and compounds are computed by use of the values for percentage composition of the different materials as shown in Tables I and II:

TABLE VI.—*Weight, composition, and heat of combustion of foods—Metabolism experiment No. 12.*

Laboratory No.	Food material.	Weight per day.	Water.	Protein.	Fat.	Carbohydrates.	Nitrogen.	Carbon.	Hydrogen.	Heat of combustion.
		Grams.	*Grams.*	*Grams.*	*Grams.*	*Grams.*	*Grams.*	*Grams.*	*Grams.*	*Calories.*
2860	Beef	175.0	114.3	47.9	9.8	....	7.67	31.24	4.57	350
2858	Deviled ham	50.0	20.7	9.2	18.2	....	1.47	18.05	2.73	218
2861	Butter	95.0	10.4	.5	82.1	....	.08	60.62	9.63	751
2857	Whole milk	900.0	787.5	27.6	40.5	37.8	4.41	59.13	9.00	718
2859	Bread	300.0	121.2	28.3	3.0	144.3	4.53	81.81	11.76	799
	Maize breakfast food	60.0	2.9	7.1	4.9	44.0	1.13	26.67	3.90	266
	Sugar	70.0	....	....	....	70.0	....	29.47	4.54	277
	Total	1,650.0	1,057.0	120.6	158.5	296.1	19.29	306.99	46.13	3,379
	Alcohol	72.4	....	....	....	....	....	37.77	9.45	512
	Total	....	....	....	....	....	19.29	344.76	55.58	3,891

TABLE VII.—*Weight, composition, and heat of combustion of feces—Metabolism experiment No. 12.*

Laboratory No.		Weight.	Water.	Protein.	Fat.	Carbohydrates.	Nitrogen.	Carbon.	Hydrogen.	Heat of combustion.
		Grams.	*Grams.*	*Grams.*	*Grams.*	*Grams.*	*Grams.*	*Grams.*	*Grams.*	*Calories.*
2862	Total, four days	370.0	274.2	31.1	25.9	22.6	5.00	48.29	6.85	545
	Average per day	92.5	68.6	7.8	6.5	5.7	1.25	12.07	1.71	136

The separations between the feces from the food consumed during the experiment and those from the food consumed before and after were made by means of charcoal, as described on page 239. Inasmuch as separations made in this way are at the best not as satisfactory as might be desired, no attempt was made to determine the excreta from the food on different days of the experiment. It is assumed that, when the food and exercise are so nearly uniform, the undigested residues and metabolic products would not vary a great deal from day to day. Even if there were irregularities from day to day they would hardly be large enough to affect very greatly the average for the whole experiment.

The amount, specific gravity, and nitrogen of the urine for the different 6-hour periods during the experiment are shown in Table VIII, and the carbon, hydrogen, water, and energy of the daily urine in Table IX. The urine was also collected during the preliminary period of 4 days and during 12 hours following the experiment. Aliquot portions (from one-half to two-thirds) in these 6-hour periods were taken for the preparation of a composite sample of the urine for the day, and in like manner aliquot portions (about one-eighth of the total weight of urine) of the composite sample of the urine for 24 hours were taken for the preparation of a composite sample for the whole period of the experiment. The nitrogen was determined in the urine for each day and in the composite for 4 days of the experiment. The quantities of nitrogen eliminated each day, as determined from the 6-hour periods and from the composite sample for the day, do not always agree exactly. Such discrepancies may be due in part to small errors in the sampling of the composites, in part to errors in the amount of urine measured out for analysis, and in part to errors in the analyses. Samples were measured out for analyses in a calibrated 5-c. c. pipette, and it is possible that differences in the amount delivered from time to time might introduce slight errors in the results. It is assumed, where discrepancies exist, that the values obtained from the 6-hour periods are the more accurate, and these latter are consequently used in the estimation of the nitrogen balance.

It is difficult to evaporate urine to dryness without more or less decomposition of urea to ammonium carbonate, and consequent loss of energy. Accordingly, no attempt was made to determine the solid matter in the urine of individual days, but a portion of the composite sample for the experiment was dried according to the manner described on page 239 and the residue used for the determination of carbon, hydrogen, and heat of combustion. The heat of combustion is also determined in the composite samples of the fresh urine each day, as explained above. The precautions taken to avoid error through loss of nitrogen, carbon, and energy during the process of drying of the urine have been described in the publication referred to on page 239.

The nitrogen is determined in the fresh urine from day to day, but in order to obtain an approximate measure of the amount of carbon and hydrogen in the urine on the successive days of the experiment some computations are necessary. In making these computations it is assumed that the ratio of nitrogen to carbon, hydrogen or water-free substance will be the same for each individual day as for the 4 days. Thus, the amount of nitrogen in the urine of the first day of the experiment was 17.62 grams, and that for the whole experiment 71.86 grams. The carbon for the whole experiment was found by actual determinations to be 49.15 grams. The computations for the amount of carbon in the urine for the first day would then be as follows: $71.86 : 49.15 :: 17.62 : x\ (=12.05)$. This method of estimating the carbon and hydrogen in the urine on the different days is manifestly more accurate than would be the case if the total quantity of carbon and hydrogen in the urine for the experiment were divided by the number of days, as is done in estimating the daily excretion through the feces. We know that the quantities of nitrogen and carbon in the urine vary from day to day, and have an accurate measure of the variation of the nitrogen, and, since the variation in the nitrogen must involve variations in the amount of carbon united with this nitrogen in the form of urea and allied compounds, it does not seem inappropriate to take the variations in the nitrogen as a measure of the corresponding variations in the carbon. Of course, there may be varying quantities of non-nitrogenous compounds in the urine from day to day, which would render the above method of estimation more or less inaccurate. It is probable, however, that the variations in nitrogen give the fairest measure of the variations in carbon and hydrogen. As a matter of fact, it has been found that the heat of combustion varies in close relation to the nitrogen. Of course, the results for the experiment as a whole are not affected by the subdivisions of the amounts for the individual days.

TABLE VIII.—*Amount, specific gravity, and nitrogen of urine by 6-hour periods—Metabolism experiment No. 12.*

Date.	Period.	Amount.	Specific gravity.	Nitrogen.	
1898.		*Grams.*		*Per cent.*	*Grams.*
Apr. 12–13	7 a. m. to 1 p. m.	309.4	1.026	1.18	3.64
	1 p. m. to 7 p. m.	349.0	1.030	1.51	5.28
	7 p. m. to 1 a. m.	247.6	1.027	1.90	4.70
	1 a. m. to 7 a. m.	187.0	1.030	2.14	4.00
	Total	1,093.0			17.62
	Total by composite	1,093.0	1.028	1.64	
13–14	7 a. m. to 1 p. m.	316.7	1.025	1.40	4.42
	1 p. m. to 7 p. m.	455.4	1.029	1.29	5.89
	7 p. m. to 1 a. m.	276.4	1.027	1.84	5.07
	1 a. m. to 7 a. m.	286.0	1.028	2.00	5.73
	Total	1,334.5			21.11
	Total by composite	1,334.5	1.028	1.59	
14–15	7 a. m. to 1 p. m.	243.6	1.024	1.14	2.78
	1 p. m. to 7 p. m.	386.3	1.024	1.24	4.78
	7 p. m. to 1 a. m.	285.4	1.025	1.72	4.91
	1 a. m. to 7 a. m.	154.3	1.030	2.06	3.18
	Total	1,069.6			15.65
	Total by composite	1,069.6	1.025	1.48	
15–16	7 a. m. to 1 p. m.	320.5	1.024	1.39	4.45
	1 p. m. to 7 p. m.	326.0	1.026	1.32	4.30
	7 p. m. to 1 a. m.	333.3	1.028	1.65	5.49
	1 a. m. to 7 a. m.	160.3	1.028	2.02	3.24
	Total	1,140.1			17.48
	Total by composite	1,140.1	1.026	1.51	
	Total for 4 days, by periods	4,637.2			71.86
16	7 a. m. to 1 p. m.	325.8		.73	2.38

TABLE IX.—*Daily elimination of carbon, hydrogen, water, and energy in urine—Metabolism experiment No. 12.*

Date.	Amount.	Carbon.		Hydrogen.		Water.		Heat of combustion.	
								Per gram.	Total.
1898.	*Grams.*	*Per ct.*	*Grams.*	*Per ct.*	*Grams.*	*Per ct.*	*Grams.*	*Calories.*	*Calories.*
Apr. 12 to 13	1,093.0		12.05		3.30		1,025.9	0.112	123
13 to 14	1,334.5		14.44		3.95		1,254.1	.108	145
14 to 15	1,069.6		10.70		2.93		1,010.0	.115	123
15 to 16	1,140.1		11.96		3.27		1,073.6	.114	130
Total	4,637.2	1.06	49.15	29	13.45	94.1	4,363.6	(.112)	[a]521

[a] The heat of combustion of the urine was determined in the composite sample for each day and in the total composite for four days. The total heat of combustion of the urine for the experiment, as determined in the latter sample, was 0.112 calorie per gram, or a total of 519 calories.

Carbon dioxid and water of respiration and perspiration.—The determinations of carbon dioxid and water in the ventilating air current in this experiment are shown in Tables XI and XII, which follow. Table X gives the total amounts of carbon dioxid and of water in the air of the chamber at the close of each period and the gain or loss during the period. Differences in the amounts in the chamber at the beginning and end of a given period—"residual" amounts, as they are here termed—indicate whether the ventilating air current has removed more or less carbon dioxid and water than was actually exhaled by the subject during the corresponding period. For instance, if a change from rest to work is made during a given period, the quantities of carbon dioxid and water given off will be increased, and the air remaining in the chamber at the end of the period will contain a larger amount of these products than was present in the air of the chamber at the beginning. This increase must be added to the amount actually found in the ventilating air current in order to obtain the actual amount exhaled during the interval. On the other hand when the transition is made from a period of considerable activity to one of rest, there is a gradual diminution of the quantity of residual carbon dioxid and water in the air of the chamber. This residual carbon dioxid is carried out in the ventilating air current during the period, but was actually given off during some preceding period. The total amount measured must, therefore, be diminished by the difference in the quantities of residual carbon dioxid at the beginning and end of the period. Furthermore, with the increased water content of the air consequent upon increased muscular work, the amount of water accumulated by condensation upon the water system or "absorbers" may be gradually increased. Indeed, the amount of water thus condensed in periods of active work is apt to be so large that a portion gradually drips from the troughs or shields beneath the water system into the "drip flasks" suspended at the end of the shields. This water is called "drip." The weight of the water system or absorbers also increases through the condensation of moisture which does not run off into the drip. On the other hand, with the change from work to rest, the weight of the absorbers diminishes because of evaporation of some of the moisture condensed thereon during the previous period.

In order to determine the actual amount of carbon dioxid and water vapor in the air of the chamber at the close of each period, samples of the air are drawn and the quantities of carbon dioxid and water determined. At the same time the absorbers are weighed and the drip collected. The data thus obtained, shown in Table X, serve for correcting the amounts of carbon dioxid and water found in the ventilating air current, as shown in Tables XI and XII beyond.

In experiment No. 12 drip was not weighed at the end of each period, but was poured into a bottle and the total amount for each 24 hours passed out at the close of the day and weighed. We have, therefore, no measure of the amount of drip in the different periods. It is altogether improbable that the amount was uniform from period to period, but in lack of any indication as to how it should be subdivided, the amounts have been apportioned equally among the four periods of the day. While this may introduce some error in individual periods, it does not affect the accuracy of the figures for the whole day.

TABLE X.—*Comparison of residual amounts of carbon dioxid and water in the chamber at the beginning and end of each period and the corresponding gain or loss—Metabolism experiment No. 12.*

Date.	End of period.	Carbon dioxid. Total amount in chamber.	Carbon dioxid. Gain (+) or loss (−) over preceding period.	Water. Total amount of vapor remaining in chamber.	Water. Gain (+) or loss (−) over preceding period.	Water. Change in weight of absorbers. Gain (+) or loss (−).	Water. Drip from absorbers.	Water. Total amount gained (+) or lost (−) during period.
1898.		*Grams.*	*Grams.*	*Grams.*	*Grams.*	*Grams.*	*Grams.*	*Grams.*
Apr. 12–13	7 a. m.	29.3	....	40.7	....	....	....	....
	1 p. m.	93.6	−64.3	58.4	−17.7	−286	191.5	495.2
	7 p. m.	71.5	−22.1	57.6	− .8	−166	191.6	24.8
	1 a. m.	31.4	−40.1	56.6	− 1.0	− 34	191.6	156.6
	7 a. m.	30.5	− .9	51.2	− 5.4	− 34	191.6	152.2
	Total	....	− 1.2	....	+10.5	− 52	766.3	828.8
13–14	1 p. m.	99.5	−69.0	61.9	−10.7	−112	298.0	420.7
	7 p. m.	79.0	−20.5	64.9	+ 3.0	− 9	298.0	292.0
	1 a. m.	31.4	−47.3	57.6	− 7.3	− 25	297.9	265.6
	7 a. m.	26.9	− 4.8	51.8	− 5.8	− 25	297.9	267.1
	Total	....	− 3.6	....	− .6	− 53	1,191.8	1,245.4
14–15	1 p. m.	88.2	+61.3	60.2	+ 8.4	− 77	251.3	336.7
	7 p. m.	74.4	−13.8	63.8	− 3.6	− 11	251.3	265.9
	1 a. m.	25.1	−49.3	56.0	− 7.8	− 81	251.2	162.4
	7 a. m.	27.1	− 2.0	50.7	− 5.3	− 81	251.2	164.9
	Total	....	+ .2	....	− 1.1	− 74	1,005.0	929.9

TABLE X.—*Comparison of residual amounts of carbon dioxid and water in the chamber, etc.*—Continued.

Date.	End of period.	Carbon dioxid. Total amount in chamber.	Carbon dioxid. Gain (+) or loss (−) over preceding period.	Water. Total amount of vapor remaining in chamber.	Water. Gain (+) or loss (−) over preceding period.	Water. Change in weight of absorbers. Gain (+) or loss (−).	Water. Drip from absorbers.	Water. Total amount gained (+) or lost (−) during period.
1898.		*Grams.*	*Grams.*	*Grams.*	*Grams.*	*Grams.*	*Grams.*	*Grams.*
15–16..	1 p. m	81.5	+54.4	61.1	+10.4	+110	233.0	353.4
	7 p. m	32.1	−49.4	61.4	+ .3	+106	233.0	339.3
	1 a. m	30.2	− 1.9	54.3	− 7.1	− 36	232.9	189.8
	7 a. m	27.4	− 2.8	50.6	− 3.7	− 36	232.9	193.2
	Total	....	+ .3	....	− .1	+144	931.8	1,075.7
	Total for 4 days	....	− 1.9	....	+ 9.9	+175	3,894.9	4,079.8

The determinations of carbon dioxid in the ventilating air current in this experiment are given in detail in Table XI. This table shows the total ventilation in liters during each 6-hour period, and the quantity of carbon dioxid in the incoming air and in the outgoing air. The difference between the carbon dioxid in the incoming and outgoing air, corrected for changes in the amount of residual carbon dioxid, gives the amount actually exhaled by the subject. Three-elevenths of this amount is taken as the quantity of carbon.

The letters in the column headings of these tables serve to indicate how the quantities in the different columns are obtained.

TABLE XI.—*Record of carbon dioxid in ventilating air current—Metabolism experiment No. 12.*

Date.	Period.	(*a*) Ventilation. Number of liters of air.	Carbon dioxid. In incoming air. (*b*) Per liter.	Carbon dioxid. In incoming air. (*c*) Total. $a \times b$.	(*d*) In outgoing air.	(*e*) Total excess in outgoing air. $d-c$.	(*f*) Correction for amount remaining in chamber.	(*g*) Corrected amount exhaled by subject. $e \times f$.	(*h*) Total weight of carbon exhaled. $g \times \frac{3}{11}$.
1898.		*Liters.*	*Mg.*	*Grams.*	*Grams.*	*Grams.*	*Grams.*	*Grams.*	*Grams.*
Apr. 12.....	7 a. m.–1 p. m	25,653	0.750	19.2	434.0	414.8	+64.3	479.1	130.7
	1 p. m.–7 p. m	25,653	.578	14.8	477.7	462.9	−22.1	440.8	120.2
12–13..	7 p. m.–1 a. m	25,653	.502	12.9	261.3	248.4	−40.1	208.3	56.8
13.....	1 a. m.–7 a. m	26,430	.617	16.3	168.0	151.7	− .9	150.8	41.1
	Total	103,389	....	63.2	1,341.0	1,277.8	+ 1.2	1,279.0	348.8
13.....	7 a. m.–1 p. m	24,875	.569	14.2	434.3	420.1	+69.0	489.1	133.4
	1 p. m.–7 p. m	26,430	.608	16.1	497.8	481.7	−20.5	461.2	125.8
13–14..	7 p. m.–1 a. m	26,430	.651	17.2	289.2	272.0	−47.3	224.7	61.3
14.....	1 a. m.–7 a. m	26,430	.690	18.2	160.4	142.2	− 4.8	137.4	37.5
	Total	104,165	....	65.7	1,381.7	1,316.0	− 3.6	1,312.4	358.0
14.....	7 a. m.–1 p. m	26,430	.572	15.1	408.0	392.9	+61.3	454.2	123.9
	1 p. m.–7 p. m	25,653	.651	14.1	462.4	448.3	−13.8	434.5	118.5
14–15..	7 p. m.–1 a. m	27,208	.644	14.8	270.5	255.7	−49.3	206.4	56.3
15.....	1 a. m.–7 a. m	26,430	.612	13.5	159.6	146.1	+ 2.0	148.1	40.4
	Total	105,721	....	57.5	1,300.5	1,243.0	+ .2	1,243.2	339.1
15.....	7 a. m.–1 p. m	27,208	.565	15.4	400.2	384.8	+54.4	439.2	119.8
	1 p. m.–7 p. m	26,430	.596	15.8	447.2	431.4	−49.4	382.0	104.2
15–16..	7 p. m.–1 a. m	27,208	.560	15.2	275.3	260.1	− 1.9	258.2	70.4
16.....	1 a. m.–7 a. m	26,430	.545	14.4	158.0	143.6	− 2.8	140.8	38.4
	Total	107,276	....	60.8	1,280.7	1,219.9	+ .3	1,220.2	332.8
	Total, 4 days.	420,551	....	247.2	....	....	....	....	1,378.7

The quantity of water exhaled by the subject in the different periods of the experiment are shown in Table XII. Unlike the carbon dioxid, the major portion of the water exhaled is condensed either within the chamber as drip, upon the surface of the absorbers, or in the "freezer" cans, which are immersed in a brine tank cooled to about −20 C., and through which the ventilating air current passes. Table XII shows the amount of water in the ingoing air, the amount in the outgoing air not condensed in the freezers, and the correction for water remaining in the chamber. The final column of the table shows the total water of respiration and perspiration during the different periods of this experiment.

TABLE XII.—*Record of water in ventilating air current—Metabolism experiment No. 12.*

Date.	Period.	(a) Ventilation. Number of liters of air.	Water in incoming air. (b) Per liter.	(c) Total, $a \times b$.	Water in outgoing air. (d) Amount condensed in freezers.	(e) Amount not condensed in freezers.	(f) Total, $d+e$.	(g) Total excess water in outgoing air, $f-c$.	(h) Correction for water remaining in chamber.	(i) Total water of respiration and perspiration, $g+h$.
1898.		*Liters.*	*Mgs.*	*Grams.*	*Grams.*	*Grams.*	*Grams.*	*Grams.*	*Grams.*	*Grams.*
Apr. 12–13 ..	7 a. m. to 1 p. m....	25,653	1.025	26.3	250.6	64.3	314.9	288.6	495.2	783.8
	1 p. m. to 7 p. m....	25,653	.884	22.7	290.8	45.7	336.5	313.8	24.8	338.6
	7 p. m. to 1 a. m....	25,653	.807	20.7	279.0	42.6	321.6	300.9	156.6	457.5
	1 a. m. to 7 a. m....	26,430	.821	21.7	254.5	36.2	290.7	269.0	152.2	421.2
	Total	103,389	....	91.4	1,074.9	188.8	1,263.7	1,172.3	828.8	2,001.1
13–14 ..	7 a. m. to 1 p. m....	24,875	.973	24.2	281.1	41.3	322.4	298.2	420.7	718.9
	1 p. m. to 7 p. m....	26,430	.844	22.3	319.1	39.0	358.1	335.8	292.0	627.8
	7 p. m. to 1 a. m....	26,430	.867	22.9	295.0	42.4	337.4	314.5	265.6	580.1
	1 a. m. to 7 a. m....	26,430	.829	21.9	265.3	34.7	300.0	278.1	267.1	545.2
	Total	104,165	....	91.3	1,160.5	157.4	1,317.9	1,226.6	1,245.4	2,472.0
14–15 ..	7 a. m. to 1 p. m....	26,430	.974	25.7	283.3	43.8	327.1	301.4	336.7	638.1
	1 p. m. to 7 p. m....	25,653	.864	22.2	301.0	40.6	341.6	319.4	265.9	585.3
	7 p. m. to 1 a. m....	27,208	.788	21.4	284.1	39.1	323.2	301.8	162.4	464.2
	1 a. m. to 7 a. m....	26,430	.811	21.4	262.6	35.8	298.4	277.0	164.9	441.9
	Total	105,721	....	90.7	1,131.0	159.3	1,290.3	1,199.6	929.9	2,129.5
15–16 ..	7 a. m. to 1 p. m....	27,208	.953	25.9	290.2	43.3	333.5	307.6	353.4	661.0
	1 p. m. to 7 p. m....	26,430	.905	23.9	306.5	43.9	350.4	326.5	339.3	665.8
	7 p. m. to 1 a. m....	27,208	.803	21.8	289.2	59.1	348.3	326.5	189.8	516.3
	1 a. m. to 7 a. m....	26,430	.767	20.3	261.1	35.1	296.2	275.9	193.2	469.1
	Total	107,276	....	91.9	1,147.0	181.4	1,328.4	1,236.5	1,075.7	2,312.2
	Total 4 days.	420,551	....	365.3	4,513.4	686.9	5,200.3	4,835.0	4,079.8	8,914.8

Heat measurements.—The details of the measurements of heat given off by the subject during the experiment are too extensive to be given here. Those for each hour of the day and night, as recorded, fill a page of a notebook sheet 22 by 29 cm. For a detailed description of the appliances for determining the amount of heat carried out by the water current and for avoiding gain or loss of heat from the apparatus except where it can be determined, reference may be made to an earlier publication on this subject.[a] As has already been explained (see p. 237), the larger part of the heat given off by the subject is carried away in the water current, whose temperature as it enters and leaves the apparatus is determined at intervals of from 2 to 4 minutes, and whose quantity is measured in cylinders holding 10 liters each. The average difference in temperature between the incoming and outgoing water multiplied by the number of kilograms of water which has passed through the chamber gives the number of calories of heat removed during the time. Since, however, the specific heat of water varies at different temperatures, it

[a] Bulletin 63 of Office of Experiment Stations, above referred to.

is our custom to reduce all these measurements of heat to the calorie at 20° C. To this end it is necessary to multiply the number of calories of heat removed in the water current at the mean difference of temperature between the incoming and outgoing current by the mean specific heat of water for that range. The product gives the corrected heat measured in terms of calories at 20° C. or $C°_{20}$. These corrected values appear in the first column of Table XIII. For a more detailed discussion of this subject see page 55 of Bulletin 63. above referred to.

The heat measured in terms of $C°_{20}$ does not represent all of the heat given off by the subject during a given period, but must be corrected for changes in temperature of the calorimeter and for the heat introduced or removed by articles of food and drink taken into or removed from the chamber, and for the heat required to vaporize the excess of water given off in the outgoing as compared with the incoming air current; i. e., latent heat of vaporization of water given off from the lungs and skin.

The temperatures of the inner walls of the calorimeter are observed at the beginning and end of each period. If these walls are warmer at the end than at the beginning of the period, some heat has been absorbed. If they are cooler, some heat has been added to the air of the chamber. For a rise in temperature of 1° C. it has been found that the walls absorb 60 calories of heat, and vice versa, in cooling 1° they give up 60 calories of heat. The changes of temperature are, however, kept so nearly constant as to vary rarely more than a tenth of a degree between the beginning and end of any period.

The temperature of the drink is taken immediately before it is passed into the chamber, and corrections are made for heat introduced by the hot coffee, or required to bring the cold water to the temperature of the chamber. The temperature of the food is brought as nearly as possible to that of the chamber before being sent in to the subject, so that little or no heat is added to or removed from the apparatus in this way. The corrections for temperature of food and drink and the dishes containing them are shown in column *d* of Table XIII.

From the best data available it appears that 0.592 calorie of heat is required for the vaporization of one gram of water at the temperature of $C°_{20}$. Water which condenses on the absorbers and is removed as drip gives up this latent heat of vaporization within the chamber and it is measured by the water current. The water which passes out from the chamber in the form of vapor in the ventilating air current carries out, however, a considerable quantity of latent heat. The amount of water vaporized is found by taking the algebraic difference between the total excess of water in the outgoing air, as shown in column *g* of Table XII, and the gain or loss of water vapor in the air of the chamber, as shown in the fourth column of Table X. The amount of water thus vaporized multiplied by 0.592, the heat of vaporization of 1 gram, gives the total heat removed by the vaporization of water within the chamber.

The heat carried away in the water current, as measured in terms of $C°_{20}$, corrected for change in temperature of calorimeter and for temperature of food and drink introduced into the chamber, added to the amount removed in the water vapor, gives the total heat determined, as shown in column *g* of Table XIII.

TABLE XIII.—*Summary of calorimetric measurements—Metabolism experiment No. 12.*

Date.	Period.	(a) Heat measured in terms of $C°_{20}$.	(b) Change of temperature of calorimeter.	(c) Capacity correction of calorimeter $b \times 60$.	(d) Correction due to temperature of food and dishes.	(e) Water vaporized equals total amount exhaled less amount condensed in chamber.	(f) Heat used in vaporization of water $c \times 0.592$.	(g) Total heat determined $a+c+d+f$.
1898.		*Calories.*	*Degrees.*	*Calories.*	*Calories.*	*Grams.*	*Calories.*	*Calories.*
Apr. 12-13.	7 a. m. to 1 p. m.	1,204.6	+05	+3.0	—3.3	306.3	181.3	1,385.6
	1 p. m. to 7 p. m.	1,236.9	+05	+3.0	+8.0	313.0	185.3	1,433.2
	7 p. m. to 1 a. m.	496.3	—05	—3.0	....	299.9	177.6	670.9
	1 a. m. to 7 a. m.	314.5	—10	—6.0	....	263.6	156.0	464.5
	Total	3,252.3	—05	—3.0	+4.7	1,182.8	700.2	3,954.2

TABLE XIII.—*Summary of calorimetric measurements—Metabolism experiment No. 12*—Continued.

Date.	Period.	(a) Heat measured in terms of $C°_{20}$.	(b) Change of temperature of calorimeter.	(c) Capacity correction of calorimeter $b \times 60$.	(d) Correction due to temperature of food and dishes.	(e) Water vaporized equals total amount exhaled less amount condensed in chamber.	(f) Heat used in vaporization of water $e \times 0.592$.	(g) Total heat determined $a+c+d+f$.
1898.		*Calories.*	*Degrees.*	*Calories.*	*Calories.*	*Grams.*	*Calories.*	*Calories.*
Apr. 13–14.	7 a. m. to 1 p. m	1,254.3	+15	+ 9.0	+ .4	308.9	182.9	1,446.6
	1 p. m. to 7 p. m	1,265.3	—10	— 6.0	+ 9.8	338.8	200.6	1,469.7
	7 p. m. to 1 a. m	555.3	00	.0	....	307.2	181.8	737.1
	1 a. m. to 7 a. m	279.6	....	....	....	272.3	161.2	440.8
	Total	3,354.5	+05	+ 3.0	+10.2	1,227.2	726.5	4,094.2
14–15.	7 a. m. to 1 p. m	1,163.6	—08	— 4.8	— 1.9	309.8	183.4	1,340.3
	1 p. m. to 7 p. m	1,159.0	—05	— 3.0	+ 9.2	323.0	191.2	1,356.4
	7 p. m. to 1 a. m	510.4	+08	+ 4.8	....	294.0	174.0	689.2
	1 a. m. to 7 a. m	302.2	+05	+ 3.0	....	271.7	160.9	466.1
	Total	3,135.2	....	....	+ 7.3	1,198.5	709.5	3,852.0
15–16.	7 a. m. to 1 p. m	1,124.9	+20	+12.0	— .4	318.0	188.2	1,324.7
	1 p. m. to 7 p. m	1,104.2	—10	— 6.0	+13.2	226.8	134.3	1,245.7
	7 p. m. to 1 a. m	536.5	....	....	....	419.4	248.3	784.8
	1 a. m. to 7 a. m	296.5	—05	— 3.0	....	272.2	161.1	454.6
	Total	3,062.1	+05	+ 3.0	+12.8	1,236.4	731.9	3,809.8

Elimination of unoxidized alcohol.—The urine, freezer water, and air current were tested for alcohol or products of incomplete oxidation of alcohol by the method referred to on page 258 above. The results obtained in this experiment are shown in Table XIV. It will be observed that 98 per cent of the alcohol taken with the food was apparently oxidized in the body. Inasmuch, however, as it has since been found[a] that even when alcohol forms no part of the diet there is a considerable amount of organic material in the urine, drip water, and ventilating air current which is capable of reducing the chromic acid employed, it is probable that the actual elimination of unoxidized or incompletely oxidized alcohol is considerably smaller than is indicated by the figures in the table.

TABLE XIV.—*Alcohol ingested and excreted—Metabolism experiment No. 12.*

Date.	Alcohol ingested.	Alcohol excreted, including other reducing material calculated as alcohol.					Alcohol metabolized in body.	
		In urine (distillate).	In drip (distillate).	In freezer water (distillate).	In air current.	Total.		
1898.								
Experiment No. 12.	*Grams.*	*Grams.*	*Grams.*	*Grams.*	*Grams.*	*Grams.*	*Grams.*	*Per cent.*
April 12–13	72.4	0.12	0.06	0.06	1.02	1.26	71.1	98.2
13–14	72.4	.17	.15	.04	1.07	1.43	71.0	98.1
14–15	72.4	.22	.36	.03	1.40	2.01	70.4	97.2
15–16	72.4	.11	.10	.03	1.02	1.26	71.1	98.2
Total	289.6	.62	.67	.16	4.51	5.96	283.6	....
Average per day	72.4	.16	.17	.04	1.13	1.49	70.9	97.9

[a] See Table CXXI.

The experimental data recorded in detail in the preceding tables can be summarized in "derived" tables showing the balance of income and outgo of matter and energy, the amounts of materials excreted under different conditions and at different times of the day, and other points of interest.

Nitrogen and carbon balance.—The daily income and outgo of nitrogen and carbon in this experiment are summarized in Table XV. The quantities of nitrogen and of carbon in the food, feces, and urine are derived respectively from Tables VI–VIII, the quantity of carbon in the respiratory products from Table XI, and the alcohol eliminated from Table XIV.

Nitrogenous materials and water of perspiration collected in clothing.—It will be noticed that the figures in column *c* of Table XV, nitrogen in urine, differ slightly from those given in Table VIII. The subject changed his underclothing each night. The gain in weight of the underclothes from the time they were sent into the chamber until they were sent out was taken as water absorbed, and the amount thus removed is added to that in column *e* of Table XVI, "Water in respiratory products." The underclothes taken out were extracted with distilled water, which was afterwards evaporated nearly to dryness, the residue made up to a given volume, and the nitrogen determined by the Kjeldahl method. The nitrogen thus given off amounted, in this experiment, to 0.96 gram for the 4 days. This amount has been divided equally between the different days of the experiment and added to the amount of nitrogen in the urine. The sums are given in column *c* of the following table:

TABLE XV.—*Income and outgo of nitrogen and carbon—Metabolism experiment No. 12.*

Date and period.	Nitrogen.				Carbon.					
	(*a*) In food.	(*b*) In feces.	(*c*) In urine.[a]	(*d*) Gain (+) or loss (—) *a*—(*b*+*c*).	(*e*) In food.	(*f*) In feces.	(*g*) In urine.	(*h*) In respiratory products.	(*i*) In alcohol eliminated.	(*k*) Gain (+) or loss (—) *e*—(*f*+*g*+*h*+*i*).
1898.	*Grams.*	*Grams.*	*Grams.*	*Grams.*	*Grams.*	*Grams.*	*Grams.*	*Grams.*	*Grams.*	*Grams.*
Apr. 12–13, 7 a. m. to 7 a. m.	19.3	1.3	17.9	+0.1	344.7	12.1	12.1	348.8	0.7	— 29.0
13–14, 7 a. m. to 7 a. m.	19.3	1.2	21.3	—3.2	344.8	12.1	14.4	358.0	.7	— 40.4
14–15, 7 a. m. to 7 a. m.	19.3	1.3	15.9	+2.1	344.7	12.1	10.7	339.1	1.0	— 18.2
15–16, 7 a. m. to 7 a. m.	19.3	1.2	17.7	+ .4	344.8	12.1	12.0	332.8	.7	— 12.8
Total	77.2	5.0	72.8	— .6	1,379.0	48.4	49.2	1,378.7	3.1	—100.4
Average per day	19.3	1.3	18.2	— .2	344.8	12.1	12.3	344.7	.8	— 25.1

[a] Including nitrogen of perspiration. The nitrogen thus given off amounted to 0.96 gram for the four days, and has been divided equally between the different days of the experiment and added to the amount of nitrogen in the urine.

Hydrogen balance.—The income and outgo of hydrogen and water upon the different days of this experiment are shown in Table XVI. The figures are collated from the previous tables. The values for water of respiration and perspiration have been increased by the amount absorbed by the underclothing on each day, and therefore differ from the corresponding values as found in the last column of Table XII. The water thus absorbed by the underclothing and removed from the apparatus amounted to 63, 10, 12.3, and 7 grams, respectively, on the successive days of the experiment. The apparent loss of water is shown in column *f* of the table. The quantities in this column are always negative, since the water given off in the respiratory products is derived not only from the water taken into the system with food and drink but also from the oxidation of hydrogen and organic compounds. When, therefore, we consider the income and outgo of water, the body is apparently losing because of the oxidation of hydrogen within the body to form water. The figures of column *f*, therefore, represent water apparently but not actually lost from the body. The quantities in columns *g*, *h*, and *i* of Table XVI represent the amounts of hydrogen in organic combination in the food, feces, and urine, and the values in column *l* show the apparent gains of hydrogen. The quantities in this column are always positive, owing to the fact that the most of the hydrogen in organic combination in the food is eliminated, not in organic combination in the feces and urine, but in the form of water in the urine or respiratory products. In other words, the figures in column *l* apparently represent hydrogen gained by the body in organic compounds, but for the most part actually represent hydrogen given off as water. The total gain or loss of hydrogen for the experiment is calculated by adding together the hydrogen apparently lost as water, column *f*, and the hydrogen in organic combination apparently gained, column *l*. This total gain or loss of hydrogen is shown in column *n*. There was in this experiment a gain of hydrogen on the first day and a loss on the three following days, making an average loss for the experiment of 20.8 grams per day.

It should be said, however, that the determinations of water and consequently of hydrogen are less satisfactory than those of nitrogen, carbon and energy.

TABLE XVI.—*Income and outgo of water and hydrogen. Metabolism experiment No. 12.*

Date and period.	Water.						Hydrogen.							
	(*a*) In food.	(*b*) In drink.	(*c*) In feces.	(*d*) In urine.	(*e*) In respiratory products.	(*f*) Apparent loss $a+b-(c+d+e)$.	(*g*) In food.	(*h*) In feces.	(*i*) In urine.	(*k*) In alcohol eliminated.	(*l*) Apparent gain $g-(h+i+k)$.	(*m*) Loss from water $f\div 9$.	(*n*) Total gain + or loss — $l+m$.
1898.	*Grams.*	*Grams.*	*Grams.*	*Grams.*	*Grams.*	*Grams.*	*Grams.*	*Grams.*	*Grams.*	*Grams.*	*Grams.*	*Grams.*	*Grams.*
April 12–13, 7 a. m. to 7 a. m.	1,057	1,807.6	68.5	1,025.9	2,007.4	237.2	55.6	1.7	3.3	0.2	50.4	26.4	+24.0
13–14, 7 a. m. to 7 a. m.	1,057	1,807.6	68.6	1,254.1	2,473.0	931.1	55.6	1.7	4.0	.2	49.7	103.4	−53.7
14–15, 7 a. m. to 7 a. m.	1,057	1,807.6	68.5	1,010.0	2,141.8	355.7	55.6	1.7	2.9	.2	50.8	39.5	+11.3
16–17, 7 a. m. to 7 a. m.	1,057	1,807.6	68.6	1,073.6	2,319.2	596.8	55.6	1.7	3.3	.2	50.4	66.3	−15.9
Total	4,228	7,230.4	274.2	4,363.6	8,941.4	2,120.8	222.4	6.8	13.5	.8	201.3	235.6	−34.3
Average per day	1,057	1,807.6	68.6	1,090.9	2,235.3	530.2	55.6	1.7	3.4	.2	50.3	58.9	− 8.6

Estimated gains and losses of body protein and fat.—From the data summarized in Tables XV and XVI we may compute the gain or loss of protein, fat, and water on the successive days of the experiment. These computations are shown in Table XVII. If nitrogen is gained or lost, a corresponding gain or loss of protein is assumed. Protein compounds are here assumed to contain on the average 16 per cent of nitrogen, 53 per cent of carbon, and 7 per cent of hydrogen. Accordingly, the gain or loss of protein is computed by multiplying the gain or loss of nitrogen by 6.25, and is shown in column *b*. Whatever protein is gained or lost must, by the above assumption, contain 53 per cent of carbon and 7 per cent of hydrogen. The amounts of carbon and hydrogen in the protein gained or lost in the successive days of this experiment, as thus computed, are shown in columns *d* and *h*. The algebraic difference between the total carbon gained or lost and that in the protein gained or lost gives the amount of carbon gained or lost in other compounds, namely, fat, glycogen, etc. It is probable that the amount of glycogen in the body at the time of rising, 7 a. m., does not differ greatly from day to day, and the assumption is here made that all of the gain or loss of carbon above that in the protein gained or lost comes from change in the amount of body fat. It is assumed that average body fat contains 76.5 per cent carbon [a] and the amount of fat gained or lost is consequently computed by dividing the values in column *e* by .765, as is shown in column *f*. Assuming, as before, that there has been no change in the body content of glycogen, the algebraic difference between the total hydrogen gained or lost and that in the protein and fat gained or lost is assumed to represent the hydrogen gained or lost in the form of water.

[a] Determinations of the percentage of carbon in body fat made in this laboratory by F. G. BENEDICT and E. OSTERBERG in 1900, published in vol. 4 of the American Journal of Physiology, page 74, average 76.08 per cent. The value 0.761 was therefore used instead of 0.765 in computations of fat gained or lost in later experiments, beginning with No. 26.

These latter values are shown in column *k* of the table. The corresponding amounts of water are shown in column *l*.

So far from claiming that these assumptions and the calculations based upon them are correct, we are persuaded that they must be more or less erroneous; but until determinations can be made of the income and outgo of oxygen, we can hardly be warranted in making other assumptions than those stated above. It is our present belief that the largest errors are in the figures for water. The experimental data are recorded in such detail in previous tables that modifications in the method of computing the nitrogen, carbon, and hydrogen balance, and the gain or loss of body material can be made at any time should results of later research indicate that such modifications were desirable.

TABLE XVII.—*Gain or loss of protein (N.×6.25), fat, and water. Metabolism experiment No. 12.*

Date and period.	(*a*) Nitrogen gained (+) or lost (−).	(*b*) Protein gained (+) or lost (−) *a*×6.25.	(*c*) Total carbon gained (+) or lost (−).	(*d*) Carbon in protein gained (+) or lost (−) *b*×.53.	(*e*) Carbon in fat, etc., gained (+) or lost (−) *c*−*d*.	(*f*) Fat gained (+) or lost (−) *e*÷.765.	(*g*) Total hydrogen gained (+) or lost (−).	(*h*) Hydrogen in protein gained (+) or lost (−) *b*×.07.	(*i*) Hydrogen in fat gained (+) or lost (−) *f*×.118.	(*k*) Hydrogen in water, etc., gained (+) or lost (−) *g*−(*h*+*i*).	(*l*) Water gained (+) or lost (−) *k*×9.
1898.	*Grams.*	*Grams.*	*Grams.*	*Grams.*	*Grams.*	*Grams.*	*Grams.*	*Grams.*	*Grams.*	*Grams.*	*Grams.*
April 12–13, 7 a. m. to 7 a. m.	+0.1	+ 0.6	− 29.0	+ 0.3	−29.3	− 38.3	+24.0	0.0	− 4.5	+28.5	+256.5
13–14, 7 a. m. to 7 a. m.	−3.2	−20.0	− 40.4	−10.6	−29.8	− 39.0	−53.7	−1.4	− 4.6	−47.7	−429.3
14–15, 7 a. m. to 7 a. m.	+2.1	+13.1	− 18.2	+ 7.0	−25.2	− 32.9	+11.3	+ .9	− 3.9	+14.3	+128.7
16–17, 7 a. m. to 7 a. m.	+ .4	+ 2.5	− 12.8	+ 1.3	−14.1	− 18.4	−15.9	+ .2	− 2.2	−13.9	−125.1
Total	− .6	− 3.8	−100.4	− 2.0	−98.4	−128.6	−34.3	− .3	−15.2	−18.8	−169.2
Average per day	− .2	− 1.0	− 25.1	− .5	−24.6	− 32.2	− 8.6	− .1	− 3.8	− 4.7	− 42.3

Balance of energy.—The income and outgo of energy are shown in Table XVIII. The figures for heats of combustion of food and unoxidized materials of feces and urine are taken from Tables VI, VII, and VIII, respectively. The values in column *d*, heat of combustion of alcohol eliminated, are derived from the corresponding values in the fifth column of Table XIV by multiplying the total alcohol unoxidized, as there given, by the heat of combustion per gram, 7.067 calories. As explained on page 258, small quantities of organic matter in the ventilating air current were reckoned as alcohol, hence the figures in column *d* somewhat overstate the heat of combustion of the alcohol given off unoxidized. The values in column *e* are obtained by multiplying the number of grams of protein gained or lost by the heat of combustion of one gram of protein, which is taken as 5.65 calories. The estimated heat of combustion of fat gained or lost, as shown in column *f*, is computed for the different days from the corresponding values in Table XVII upon the supposition that each gram of fat has a heat of combustion of 9.5 calories,[a] which has been found to be not far from the average for one gram of various animal fats. The estimates of column *g* are the heats of combustion of the food eaten less the algebraic sum of the heats of combustion of food, feces, and body material gained or lost. To put it in another way, they are the heats of combustion of the food eaten and of body material lost less the heats of combustion of feces, urine, and body material stored. They may be said to represent the net income of energy to the body. The net outgo is measured directly by the apparatus, and is shown in column *h* of Table XVIII. The net income averages in this experiment 5 calories per day less than the net outgo. On different days of the experiment the net outgo varied from 25 calories below to 35 calories above the net income.

[a] Determinations of the heat of combustion of human body fat made in this laboratory by F. G. BENEDICT and E. OSTERBERG in 1900, and published in volume 4 of the American Journal of Physiology, page 76, indicate that the heat of combustion of body fat is nearly 9.54 calories per gram. This value was used in the computations of later experiments, beginning with No. 26. (See discussion of this subject by Atwater and Bryant in Report of the Storrs (Conn.) Experiment Station for 1899, p. 93.)

TABLE XVIII.—*Income and outgo of energy.—Metabolism experiment No. 12.*

Date and period.	(a) Heat of combustion of food eaten.	(b) Heat of combustion of feces.	(c) Heat of combustion of urine.	(d) Heat of combustion of alcohol eliminated.	(e) Estimated heat of combustion of protein gained (+) or lost (−).	(f) Estimated heat of combustion of fat gained (+) or lost (−).	(g) Estimated energy of material oxidized in the body $a-(b+c+d+e+f)$.	(h) Heat determined.	(i) Heat determined greater (+) or less (−) than estimated $h-g$.	(k) Heat determined greater (+) or less (−) than estimated $i\div g$.
1898.	*Calories.*	*Calories.*	*Calories.*	*Calories.*	*Calories.*	*Calories.*	*Calories.*	*Calories.*	*Calories.*	*Per cent.*
Apr. 12–13, 7 a. m. to 7 a. m	3,891	136	123	9	+ 4	− 360	3,979	3,954	−25	−0.6
13–14, 7 a. m. to 7 a. m	3,891	136	145	10	−115	− 367	4,082	4,094	+12	+0.3
14–15, 7 a. m. to 7 a. m	3,891	136	123	14	+ 75	− 309	3,852	3,852	0	0.0
15–16, 7 a. m. to 7 a. m	3,891	136	130	9	+ 14	− 173	3,775	3,810	+35	+0.9
Total	15,564	544	521	42	− 22	−1,209	15,688	15,710	+22	....
Average per day.........	3,891	136	130	11	− 6	− 302	3,922	3,927	+ 5	+0.1

EXPERIMENTS NOS. 15–17—REST, WITH ALCOHOL DIET.

Subject.—E. O., who was the subject of No. 12. His weight without clothing was about 71 kilograms (156 pounds).

Occupation during experiment.—Reading, writing, etc., with as little mental and muscular activity as was compatible with comfort.

Duration.—Preliminary period 4 days, beginning with breakfast January 12, 1899. The series of experiments Nos. 15–17 began at 7 a. m., January 16, and ended at 7 a. m., January 22. The whole period was thus 6 days, of which 2 days were given to each experiment. The subject entered the respiration chamber on the evening of January 15. The total time spent in the chamber was thus 7 nights and 6 days.

Diet.—Ordinary food furnishing, per day, 109 grams of protein and 2,141 calories of energy, and in addition 72.5 grams of absolute alcohol, furnishing 512 calories of energy, making the total energy of the diet 2,653 calories. The alcohol was taken in 6 doses, 3 with the meals and the other 3 between meals and just before retiring.

In experiment No. 15 commercial ethyl alcohol was added to a sweetened coffee infusion, as in experiment No. 12. To 775.2 grams of coffee infusion were added 45 grams of sugar and 79.8 grams of 90.9 per cent commercial ethyl alcohol, making a total of 900 grams of the mixture, containing 782.5 grams of water.

In experiment No. 16 whisky containing 45.8 per cent ethyl alcohol by weight was used. Instead of adding the whisky to the coffee infusion it was taken with sugar in water. The whisky and sugar were added to the water by the subject within the calorimeter, in the proportion of 158.3 grams whisky, 45 grams sugar, and 696.7 grams water, making a total of 900 grams, containing 782.5 grams of water and 72.5 grams absolute alcohol, as in experiment No. 15. An apparent increase in the alcohol found in the ventilating air current during experiment No. 16 led us to believe that some alcohol might be evaporated during the admixture of whisky and water in the apparatus, and in the following experiments the mixture of alcohol with coffee or water was prepared outside, as had been done in all cases previous to No. 16.

In experiment No. 17 the alcohol was administered in the form of brandy, containing 50.4 per cent alcohol by weight. To 711.2 grams of water were added 45 grams of sugar and 143.8 grams of brandy, thus furnishing the same amount of water and alcohol as in the previous experiments. The alcohol in the whisky and brandy was determined by the usual method of distillation and determination of the specific gravity of the distillate.[a]

[a] See Methods of Analysis, U. S. Dept. Agr., Division of Chemistry, Bulletin 46 (revised), p. 57.

Diet in metabolism experiments Nos. 15–17.

FOOD.

	Breakfast.	Dinner.	Supper.	Total.
	Grams.	*Grams.*	*Grams.*	*Grams.*
Beef	55	105		160
Butter	7	10	13	30
Milk, skimmed	300	260	390	950
Bread	55	100	155	310
Parched cereal	30			30
Sugar	12		[a] 45	57

[a] Used in coffee infusion and alcohol.

DRINK.

Time.	Experiment No. 15.		Experiment No. 16.		Experiment No. 17.	
	Coffee infusion, sugar, and alcohol.[a]	Water.	Water, sugar, and whisky.[a]	Water.	Coffee infusion, sugar, and brandy.[a]	Water.
	Grams.	*Grams.*	*Grams.*	*Grams.*	*Grams.*	*Grams.*
Breakfast	300		300		300	
10.30 a. m		200		200		200
Dinner	300		300		300	
3.30 p. m		200		200		200
Supper	300		300		300	
10.00 p. m		200		200		200
Total	[a] 900	600	[a] 900	600	[a] 900	600

[a] Contains 72.5 grams absolute alcohol and 45 grams sugar.

Daily routine.—The general routine of the experiment was as follows:

Daily programme—Metabolism experiments Nos. 15–17.

7.00 a. m	Rise, pass urine, weigh self stripped, collect drip, and weigh absorbers.	6.30 p. m	Supper.
7.45 a. m	Breakfast.	7.00 p. m	Pass urine, collect drip, and weigh absorbers.
10.30 a. m	Drink 200 grams water.	10.00 p. m	Drink 200 grams water, weigh self stripped, take cap off food aperture, retire.
1.00 p. m	Pass urine, collect drip, and weigh absorbers.	1.00 a. m	Pass urine.
1.30 p. m	Dinner.		
3.30 p. m	Drink 200 grams water.		

The main facts recorded in the diary kept by the subject during the experiment are shown in Table XIX:

TABLE XIX.—*Summary of diary—Metabolism experiments Nos. 15–17.*

Date and time.	Weight without clothes.	Pulse rate per minute.	Temperature.	Hygrometer. Dry bulb.	Hygrometer. Wet bulb.
1899.	*Kilograms.*		*° F.*	*° C.*	*° C.*
Jan. 16, 7.00 a. m	70.9	64	98.6	20.6	15.5
1.00 p. m		66	98.8	20.6	15.8
7.00 p. m		68	99.0	20.5	16.2
10.00 p. m	71.7				
17, 7.00 a. m	70.8	59	97.2	20.7	16.0
1.00 p. m		65	98.5	20.5	15.8
10.00 p. m	71.6	66	98.6	20.8	16.9
18, 7.00 a. m	70.4	58	97.0	20.4	16.0
1.00 p. m		62	98.0	20.4	15.9
10.00 p. m	71.2	65	98.4	20.3	15.9

TABLE XIX.—*Summary of diary—Metabolism experiments Nos. 15–17*—Continued.

Date and time.	Weight without clothes.	Pulse rate per minute.	Temperature.	Hygrometer. Dry bulb.	Hygrometer. Wet bulb.
1899.	*Kilograms.*		° *F.*	° *C.*	° *C.*
19, 7.00 a. m.	70.3	59	97.2	20.6	15.8
1.00 p. m.	....	68	98.6	20.5	16.0
3.30 p. m.	....	....	....	20.5	16.8
7.00 p. m.	....	68	98.9	20.5	16.0
10.00 p. m.	71.2	69	98.0	20.7	16.6
20, 7.00 a. m.	70.3	55	96.8	20.7	16.0
10.40 a. m.	....	....	....	20.5	15.9
1.00 p. m.	....	60	97.8	20.4	15.6
7.00 p. m.	....	68	98.6	20.4	16.0
10.00 p. m.	71.1	70	99.0	20.4	16.7
21, 7.00 a. m.	70.2	60	98.0	20.6	15.9
9.50 a. m.	....	....	....	20.7	16.1
1.00 p. m.	....	64	98.3	20.7	15.8
7.00 p. m.	....	67	98.3	20.4	15.8
10.00 p. m.	70.9	71	98.5	20.6	16.4
22, 7.00 a. m.	70.1	60	97.8	20.5	16.0

Detailed statistics of income and outgo.—The weight, composition, and heat of combustion of food, feces, and urine are shown in Tables XX to XXIII. The gross income of nitrogen, carbon, hydrogen, and energy in the food and drink did not vary from day to day, and the outgo of each in the feces was assumed to be uniform in all the 6 days of the 3 experiments. Inasmuch as the diet was identical in the different experiments, with the exception of the substitution of whisky and brandy for the commercial ethyl alcohol, this assumption regarding the feces is probably within the limits of experimental error. The elimination of nitrogen in the urine was quite constant during the 6 days within the respiration chamber. During the 4 days of the preliminary period it amounted to 11.7, 16, 13.9, and 10.4 grams, respectively. The urine of the daily composite samples decomposed before the heat of combustion could be determined. The heat of combustion of the urine for each day has therefore been computed from that of the composite sample of the 6 days, according to the method employed for computing the carbon and hydrogen on the different individual days from the total carbon and hydrogen eliminated in the urine during the experiment.

TABLE XX.—*Weight, composition, and heat of combustion of foods—Metabolism experiments Nos. 15–17.*

Laboratory No.	Food material.	Weight per day.	Water.	Protein.	Fat.	Carbohydrates.	Nitrogen.	Carbon.	Hydrogen.	Heat of combustion.
		Grams.	*Grams.*	*Grams.*	*Grams.*	*Grams.*	*Grams.*	*Grams.*	*Grams.*	*Calories.*
3009	Beef	160	110.7	41.7	4.2	....	6.67	24.38	3.66	269
3003	Butter	30	3.1	.4	25.8	....	.06	18.57	3.12	239
3006	Milk, skimmed	950	850.3	38.9	1.0	52.3	6.18	43.79	6.27	445
2968	Bread	310	129.3	24.5	8.7	143.5	3.94	84.72	12.74	840
3004	Cereal, parched	30	1.8	3.4	.2	24.1	.55	12.42	1.85	122
	Sugar	57	....	....	....	57.0	....	24.00	3.69	226
	Total	1,537	1,095.2	108.9	39.9	276.9	17.40	207.88	31.33	2,141
	Alcohol	72.5	....	....	....	....	....	37.82	9.46	512
	Total	....	....	....	....	....	17.40	245.70	40.79	2,653

TABLE XXI.—*Weight, composition, and heat of combustion of feces—Metabolism experiments Nos. 15–17.*

Laboratory No.		Weight.	Water.	Protein.	Fat.	Carbohydrates.	Nitrogen.	Carbon.	Hydrogen.	Heat of combustion.
		Grams.	*Grams.*	*Grams.*	*Grams.*	*Grams.*	*Grams.*	*Grams.*	*Grams.*	*Calories.*
3008	Total for 6 days	315.5	215.5	30.9	17.7	27.1	4.95	46.85	6.53	528
	Average per day	52.6	35.9	5.1	3.0	4.5	.82	7.81	1.09	88

TABLE XXII.—*Amount, specific gravity, and nitrogen of urine by six-hour periods—Metabolism experiments Nos. 15-17.*

Date.	Period.	Amount.	Specific gravity.	Nitrogen.	
1899.	*Experiment No. 15.*	*Grams.*		*Per cent.*	*Grams.*
Jan. 16-17	7 a. m. to 1 p. m	406.5	1.023	0.88	3.58
	1 p. m. to 7 p. m	433.4	1.022	1.10	4.77
	7 p. m. to 1 a. m	473.6	1.018	.86	4.07
	1 a. m. to 7 a. m	165.2	1.015	1.62	2.67
	Total	1,478.7			15.09
	Total by composite	1,478.7	1.018	1.02	15.08
17-18	7 a. m. to 1 p. m	773.3	1.009	.55	4.25
	1 p. m. to 7 p. m	572.4	1.014	.83	4.75
	7 p. m. to 1 a. m	700.0	1.009	.63	4.41
	1 a. m. to 7 a. m	207.5	1.018	1.34	2.78
	Total	2,253.2			16.19
	Total by composite	2,253.2	1.011	.71	16.00
	Experiment No. 16.				
18-19	7 a. m. to 1 p. m	638.2	1.012	.64	4.08
	1 p. m. to 7 p. m	556.7	1.013	.77	4.29
	7 p. m. to 1 a. m	439.8	1.014	.93	4.09
	1 a. m. to 7 a. m	231.9	1.016	1.18	2.74
	Total	1,866.6			15.20
	Total by composite	1,866.6	1.013	.81	15.12
19-20	7 a. m. to 1 p. m	621.2	1.010	.65	4.04
	1 p. m. to 7 p. m	432.5	1.019	.98	4.24
	7 p. m. to 1 a. m	617.4	1.013	.75	4.63
	1 a. m. to 7 a. m	259.5	1.015	1.07	2.78
	Total	1,930.6			15.69
	Total by composite	1,930.6	1.013	.80	15.44
	Experiment No. 17.				
20-21	7 a. m. to 1 p. m	484.3	1.014	.79	3.83
	1 p. m. to 7 p. m	562.5	1.013	.76	4.27
	7 p. m. to 1 a. m	642.6	1.011	.77	4.95
	1 a. m. to 7 a. m	268.2	1.014	.99	2.65
	Total	1,957.6			15.70
	Total by composite	1,957.6	1.012	.80	15.66
21-22	7 a. m. to 1 p. m	757.0	1.008	.55	4.16
	1 p. m. to 7 p. m	469.8	1.016	.89	4.18
	7 p. m. to 1 a. m	571.5	1.011	.78	4.46
	1 a. m. to 7 p. m	282.3	1.016	.99	2.79
	Total	2,080.6			15.59
	Total by composite	2,080.6		.74	15.40
	Total for 6 days, by periods	11,567.3			93.46
	Composite for 6 days	11,567.3		.81	93.69

TABLE XXIII.—*Daily elimination of carbon, hydrogen, water, and energy in urine—Metabolism experiments Nos. 15-17.*

Date.	Amount.	Carbon.		Hydrogen.		Water.		Heat of combustion.	
								Per gram.	Total.
1899.									
Experiment No. 15.	*Grams.*	*P. ct.*	*Grams.*	*P. ct.*	*Grams.*	*P. ct.*	*Grams.*	*Calories.*	*Calories.*
Jan. 16-17	1,478.7		10.64		2.99		1,426.4		123.2
17-18	2,253.2		11.42		3.20		2,197.1		132.2
Experiment No. 16.									
Jan. 18-19	1,866.6		10.72		3.01		1,813.9		124.1
19-20	1,930.6		11.07		3.11		1,876.2		128.2
Experiment No. 17.									
Jan. 20-21	1,957.6		11.08		3.11		1,903.2		128.3
21-22	2,080.6		11.00		3.09		2,026.6		127.4
Total	11,567.3	0.57	65.93	0.16	18.51	97.2	11,243.4	0.066	763.4

There was but very little change in the weight of the absorbing system inside the apparatus during the experiment, and the drip from the system was very slight, so that little correction has to be made for variations in the weight of the absorbers. The details of the determinations of carbon dioxid and water are as follows:

TABLE XXIV.—*Comparison of residual amounts of carbon dioxid and water in the chamber at the beginning and end of each period, and the corresponding gain or loss—Metabolism experiments Nos. 15–17.*

Date.	End of period.	Carbon dioxid.		Water.				
		Total amount in chamber.	Gain (+) or loss (−) over preceding period.	Total amount of vapor remaining in chamber.	Gain (+) or loss (−) over preceding period.	Change in weight of absorbers. Gain (+) or loss (−).	Drip from absorbers.	Total amount gained (+) or lost (−) during the period.
1899.		*Grams.*	*Grams.*	*Grams.*	*Grams.*	*Grams.*	*Grams.*	*Grams.*
Jan. 16	7 a. m.	31.4	+ 1.0	32.9	+0.5	....	....	....
16–17	1 p. m.	37.5	+ 6.1	38.8	+5.9	+ 5	3	+13.9
	7 p. m.	39.1	+ 1.6	41.4	+2.6	− 8	3	− 2.4
	1 a. m.	25.2	−13.9	47.3	+5.9	+ 1	3	+ 9.9
	7 a. m.	26.4	+ 1.2	38.6	−8.7	+ 1	3	− 4.7
	Total	....	− 5.0	....	+5.7	− 1	12	+16.7
17–18	1 p. m.	33.3	+ 6.9	40.1	+1.5	−13	3	− 8.5
	7 p. m.	40.5	+ 7.2	41.7	+1.6	− 3	3	+ 1.6
	1 a. m.	27.4	−13.1	49.1	+7.4	+ 5	3	+15.4
	7 a. m.	31.2	+ 3.8	43.2	−5.9	+ 5	3	+ 2.1
	Total	....	+ 4.8	....	+4.6	− 6	12	+10.6
18–19	1 p. m.	35.2	+ 4.0	42.1	−1.1	+ 4	3	+ 5.9
	7 p. m.	40.7	+ 5.5	47.1	+5.0	+ 5	3	+13.0
	1 a. m.	28.4	−12.3	45.8	−1.3	− 3	3	− 1.3
	7 a. m.	25.5	− 2.9	39.4	−6.4	− 2	3	− 5.4
	Total	....	− 5.7	....	−3.8	+ 4	12	+12.2
19–20	1 p. m.	42.1	+16.6	41.6	+2.2	+11	3	+16.2
	7 p. m.	44.1	+ 2.0	45.0	+3.4	+14	3	+20.4
	1 a. m.	29.5	−14.6	46.2	+1.2	− 8	3	− 3.8
	7 a. m.	27.7	− 1.8	41.3	−4.9	− 8	3	− 9.9
	Total	....	+ 2.2	....	+1.9	+ 9	12	+22.9
20–21	1 p. m.	38.9	+11.2	39.2	−2.1	− 9	3	− 8.1
	7 p. m.	38.4	− .5	42.5	+3.3	+17	3	+23.3
	1 a. m.	29.3	− 9.1	48.6	+6.1	−11	3	− 1.9
	7 a. m.	27.7	− 1.6	40.1	−8.5	−11	3	−16.5
	Total	....	....	....	−1.2	−14	12	− 3.2
21–22	1 p. m.	38.3	+10.6	40.1	....	+11	3	+14.0
	7 p. m.	38.9	+ .6	42.2	+2.1	+14	3	+19.1
	1 a. m.	26.2	−12.7	42.9	+ .7	−19	3	−15.3
	7 a. m.	30.1	+ 3.9	38.4	−4.5	−19	3	−20.5
	Total	....	+ 2.4	....	−1.7	−13	12	− 2.7
	Total for 6 days	....	− 1.3	....	+5.5	−21	72	+56.5

TABLE XXV.—*Record of carbon dioxid in ventilating air current—Metabolism experiments Nos. 15–17.*

Date.	Period.	(a) Ventilation. Number of liters of air.	Carbon dioxid. In incoming air. (b) Per liter.	(c) Total, $a \times b$.	(d) In outgoing air.	(e) Total excess in outgoing air, $d-c$.	(f) Correction for amount remaining in chamber.	(g) Corrected amount exhaled by subject, $c+f$.	(h) Total weight of carbon exhaled, $g \times \frac{3}{11}$.
	Experiment No. 15.	*Liters.*	*Mg.*	*Grams.*	*Grams.*	*Grams.*	*Grams.*	*Grams.*	*Grams.*
1899. Jan. 16–17	7 a. m.–1 p. m.	26,341	0.621	16.4	243.5	227.1	+ 6.1	233.2	63.6
	1 p. m.–7 p. m.	27,012	.551	14.9	248.4	233.5	+ 1.6	235.1	64.2
	7 p. m.–1 a. m.	28,184	.555	15.6	228.4	212.8	−13.9	198.9	54.2
	1 a. m.–7 a. m.	27,549	.589	16.2	157.4	141.2	+ 1.2	142.4	38.8
	Total	109,086	....	63.1	877.7	814.6	− 5.0	809.6	220.8
17–18	7 a. m.–1 p. m.	26,862	.615	16.5	222.8	206.3	+ 6.9	213.2	58.2
	1 p. m.–7 p. m.	27,308	.718	19.6	240.9	221.3	+ 7.2	228.5	62.3
	7 p. m.–1 a. m.	27,663	.568	15.7	242.8	227.1	−13.1	214.0	58.4
	1 a. m.–7 a. m.	28,241	.720	20.3	164.7	144.4	+ 3.8	148.2	40.4
	Total	110,074	....	72.1	871.2	799.1	+ 4.8	803.9	219.3
	Experiment No. 16.								
18–19	7 a. m.–1 p. m.	26,544	.652	17.3	232.1	214.8	+ 4.0	218.8	59.6
	1 p. m.–7 p. m.	27,013	.666	18.0	233.1	215.1	+ 5.5	220.6	60.2
	7 p. m.–1 a. m.	28,510	.513	14.6	241.9	227.3	−12.3	215.0	58.6
	1 a. m.–7 a. m.	27,813	.551	15.3	160.7	145.4	− 2.9	142.5	38.9
	Total	109,880	....	65.2	867.8	802.6	− 5.7	796.9	217.3
19–20	7 a. m.–1 p. m.	24,950	.560	14.0	223.4	209.4	+16.6	226.0	61.6
	1 p. m.–7 p. m.	22,648	.607	13.7	249.2	235.5	+ 2.0	237.5	64.7
	7 p. m.–1 a. m.	27,492	.632	17.4	237.5	220.1	−14.6	205.5	56.1
	1 a. m.–7 a. m.	26,818	.663	17.8	154.7	136.9	− 1.8	135.1	36.9
	Total	101,908	....	62.9	864.8	801.9	+ 2.2	804.1	219.3
	Experiment No. 17.								
20–21	7 a. m.–1 p. m.	25,502	.703	17.9	218.0	200.1	+11.2	211.3	57.6
	1 p. m.–7 p. m.	26,811	.657	17.6	242.6	225.0	− .5	224.5	61.3
	7 p. m.–1 a. m.	27,935	.568	15.9	217.8	201.9	− 9.1	192.8	52.6
	1 a. m.–7 a. m.	28,699	.611	17.5	170.4	152.9	− 1.6	151.3	41.2
	Total	108,947	....	68.9	848.8	779.9	....	779.9	212.7
21–22	7 a. m.–1 p. m.	25,958	.634	16.5	222.2	205.7	+10.6	216.3	59.0
	1 p. m.–7 p. m.	26,321	.565	14.9	243.5	228.6	+ .6	229.2	62.5
	7 p. m.–1 a. m.	27,920	.554	15.5	229.2	213.7	−12.7	201.0	54.8
	1 a. m.–7 a. m.	27,829	.632	17.6	160.4	142.8	+ 3.9	146.7	40.0
	Total	108,028	....	64.5	855.3	790.8	+ 2.4	793.2	216.3
	Total, 6 days	647,923	....	396.7	5,185.6	4,788.9	− 1.3	4,787.6	1,305.7

TABLE XXVI.—*Record of water in ventilating air current—Metabolism experiments Nos. 15–17.*

Date.	Period.	(*a*) Ventilation. Number of liters of air.	Water in incoming air. (*b*) Per liter.	Water in incoming air. (*c*) Total. $a \times b$.	Water in outgoing air. (*d*) Amount condensed in freezers.	Water in outgoing air. (*e*) Amount not condensed in freezers.	Water in outgoing air. (*f*) Total. $d+e$.	(*g*) Total excess water in outgoing air, $f-c$.	(*h*) Correction for water remaining in chamber.	(*i*) Total water of respiration and perspiration. $g+h$.
	Experiment No. 15.									
1899.		*Liters.*	*Mg.*	*Grams.*	*Grams.*	*Grams.*	*Grams.*	*Grams.*	*Grams.*	*Grams.*
Jan. 16–17	7 a. m.–1 p. m.......	26,341	0.875	23.1	176.3	42.7	219.0	195.9	+13.9	209.8
	1 p. m.–7 p. m.......	27,012	.873	23.6	198.5	40.3	238.8	215.2	− 2.4	212.8
	7 p. m.–1 a. m.......	28,184	.896	25.2	225.1	50.7	275.8	250.6	+ 9.9	260.5
	1 a. m.–7 a. m.......	27,549	.851	23.4	214.1	41.8	255.9	232.5	− 4.7	227.8
	Total	109,086	....	95.3	814.0	175.5	989.5	894.2	+16.7	910.9
17–18	7 a. m.–1 p. m.......	26,862	.920	24.7	196.9	40.6	237.5	212.8	− 8.5	204.3
	1 p. m.–7 p. m.......	27,308	.979	26.7	204.6	38.6	243.2	216.5	+ 1.6	218.1
	7 p. m.–1 a. m.......	27,663	.914	25.3	248.3	45.9	294.2	268.9	+15.4	284.3
	1 a. m.–7 a. m.......	28,241	.895	25.3	241.7	41.5	283.2	257.9	+ 2.1	260.0
	Total	110.074	....	102.0	891.5	166.6	1,958.1	956.1	+10.6	966.7
	Experiment No. 16.									
18–19	7 a. m.–1 p. m.......	26,544	.999	26.5	209.7	39.3	249.0	222.5	+ 5.9	228.4
	1 p. m.–7 p. m.......	27,013	.897	24.2	214.0	38.6	252.6	228.4	+13.0	241.4
	7 p. m.–1 a. m.......	28,510	.805	22.9	230.4	41.1	271.5	248.6	− 1.3	247.3
	1 a. m.–7 a. m.......	27,813	.761	21.2	217.0	39.6	256.6	235.4	− 5.4	230.0
	Total	109,880	....	94.8	871.1	158.6	1,029.7	934.9	+12.2	947.1
19–20	7 a. m.–1 p. m.......	24,950	.784	19.6	185.7	33.2	218.9	199.3	+16.2	215.5
	1 p. m.–7 p. m.......	22,648	.783	17.7	187.6	32.0	219.6	201.9	+20.4	222.3
	7 p. m.–1 a. m.......	27,492	.818	22.5	219.7	42.2	261.9	239.4	− 3.8	235.6
	1 a. m.–7 a. m.......	26,818	.786	21.1	217.2	37.0	254.2	233.1	− 9.9	223.2
	Total	101,908	....	80.9	810.2	144.4	954.6	873.7	+22.9	896.6
	Experiment No. 17.									
20–21	7 a. m.–1 p. m.......	25,502	.853	21.7	186.5	36.3	222.8	201.1	− 8.1	193.0
	1 p. m.–7 p. m.......	26,811	.953	25.5	205.6	39.6	245.2	219.7	+23.3	243.0
	7 p. m.–1 a. m.......	27,935	.840	23.5	218.1	44.4	262.5	239.0	− 1.9	237.1
	1 a. m.–7 a. m.......	28,699	.798	22.9	229.2	40.7	269.9	247.0	−16.5	230.5
	Total	108,947	....	93.6	839.4	161.0	1,000.4	906.8	− 3.2	903.6
21–22	7 a. m.–1 p. m.......	25,958	.980	25.4	192.0	37.5	229.5	204.1	+14.0	218.1
	1 p. m.–7 p. m.......	26,321	.939	24.7	205.2	39.0	244.2	219.5	+19.1	238.6
	7 p. m.–1 a. m.......	27,920	.935	26.1	223.4	41.7	265.1	239.0	−15.3	223.7
	1 a. m.–7 a. m.......	27,829	.924	25.7	206.7	38.5	245.2	219.5	−20.5	199.0
	Total	108,028	....	101.9	827.3	156.7	984.0	882.1	− 2.7	879.4
	Total, 6 days .	647,923	....	568.5	5.053.5	962.8	6,016.3	5,447.8	+56.5	5.504.3

Table XXVII summarizes the results of the calorimetric measurements during this experiment.

TABLE XXVII.—*Summary of calorimetric measurements—Metabolism experiments Nos. 15–17.*

Date.	Period.	(*a*) Heat measured in terms of C°₂₀.	(*b*) Change of temperature of calorimeter.	(*c*) Capacity correction of calorimeter, $b \times 60$.	(*d*) Correction due to temperature of food and dishes.	(*e*) Water vaporized, equals total amount exhaled less amount condensed in chamber.	(*f*) Heat used in vaporization of water, $e \times 0.592$.	(*g*) Total heat determined, $a+c+d+f$.
	Experiment No. 15.							
1899.		*Calories.*	*Degrees.*	*Calories.*	*Calories.*	*Grams.*	*Calories.*	*Calories.*
Jan. 16–18	7 a. m. to 1 p. m.	557. 1	—0. 03	—1. 80	+ 5. 2	201. 8	119. 5	680. 0
	1 p. m. to 7 p. m.	543. 8	+ .02	+1. 20	+ .3	217. 8	128. 9	674. 2
	7 p. m. to 1 a. m.	473. 6	....	....	....	256. 5	151. 9	625. 5
	1 a. m. to 7 a. m.	269. 1	+ .01	+ .60	....	223. 8	132. 5	402. 2
	Total	1, 843. 6	.00	.00	+ 5. 5	899. 9	532. 8	2, 381. 9
17–18	7 a. m. to 1 p. m.	488. 5	— .01	— .60	+ 2. 2	214. 3	126. 9	617. 0
	1 p. m. to 7 p. m.	516. 8	— .01	— .60	+ 4. 7	218. 1	129. 1	650. 0
	7 p. m. to 1 a. m.	490. 0	....	....	....	276. 3	163. 6	653. 6
	1 a. m. to 7 a. m.	274. 8	— .03	—1. 80	....	252. 0	149. 2	422. 2
	Total	1, 770. 1	— .05	—3. 00	+ 6. 9	960. 7	568. 8	2, 342. 8
	Experiment No. 16.							
18–19	7 a. m. to 1 p. m.	531. 7	+ .02	+1. 20	+ .2	221. 4	131. 1	664. 2
	1 p. m. to 7 p. m.	484. 1	+ .01	+ .60	— 2. 5	233. 4	138. 2	620. 4
	7 p. m. to 1 a. m.	461. 9	+ .01	+ .60	....	247. 3	146. 4	608. 9
	1 a. m. to 7 a. m.	282. 0	— .05	—3. 00	....	229. 0	135. 6	414. 6
	Total	1, 759. 7	— .01	— .60	— 2. 3	931. 1	551. 3	2, 308. 1
19–20	7 a. m. to 1 p. m.	549. 6	+ .02	+1. 20	+ .9	201. 5	119. 3	671. 0
	1 p. m. to 7 p. m.	553. 3	+ .01	+ .60	+ 7. 8	205. 3	121. 5	683. 2
	7 p. m. to 1 a. m.	437. 4	+ .10	+6. 00	....	240. 6	142. 4	585. 8
	1 a. m. to 7 a. m.	286. 7	— .09	—5. 40	....	228. 2	135. 1	416. 4
	Total	1, 827. 0	+ .04	+2. 40	+ 8. 7	875. 6	518. 3	2, 356. 4
	Experiment No. 17.							
20–21	7 a. m. to 1 p. m.	465. 8	— .02	—1. 20	— .2	199. 0	117. 8	582. 2
	1 p. m. to 7 p. m.	490. 2	+ .04	+2. 40	+ 1. 2	223. 0	132. 0	625. 8
	7 p. m. to 1 a. m.	467. 7	— .04	—2. 40	....	245. 1	145. 1	610. 4
	1 a. m. to 7 a. m.	286. 7	+ .03	+1. 80	....	238. 5	141. 2	429. 7
	Total	1, 710. 4	+ .01	+ .60	+ 1. 0	905. 6	536. 1	2, 248. 1
21–22	7 a. m. to 1 p. m.	506. 0	— .02	—1. 20	— .3	204. 1	120. 8	625. 3
	1 p. m. to 7 p. m.	528. 2	— .01	— .60	— 2. 3	221. 6	131. 2	656. 5
	7 p. m. to 1 a. m.	456. 6	+ .02	+1. 20	....	239. 7	141. 9	599. 7
	1 a. m. to 7 a. m.	295. 4	— .01	— .60	....	215. 0	127. 3	422. 1
	Total	1, 786. 2	— .02	—1. 20	— 2. 6	880. 4	521. 2	2, 303. 6
	Total for 6 days	10, 697. 0	....	—1. 80	+17. 2	5, 453. 3	3, 228. 5	13, 940. 9

Elimination of unoxidized alcohol.—As has been explained on page 258 there may be a considerable amount of reducing matter in the ventilating air current when alcohol does not form a part of the diet. The determinations of the quantity of reducing matter in the air current during these experiments were made in the manner previously described, and the amounts are all reckoned as alcohol, although it is not believed that this is the case. It seems probable that the increased elimination of reducing matter in the air current on the 2 days of experiment No. 16 is due to the mixing of the whisky and water within the chamber by the subject, as already mentioned. According to the figures in Table XXVIII the subject actually metabolized 97.9 per cent of the alcohol in the diet during experiment No. 15, 96.6 per cent in experiment No. 16, and 97.9 per cent in experiment No. 17.

TABLE XXVIII.—*Alcohol ingested and excreted—Metabolism experiments Nos. 15–17.*

Date.	Alcohol ingested.	Alcohol excreted, including other reducing material calculated as alcohol.				Alcohol metabolized in body.	
		In urine (distillate).	In freezer water (distillate).	In air current.	Total.		
1899.							
Experiment No. 15.	*Grams.*	*Grams.*	*Grams.*	*Grams.*	*Grams.*	*Grams.*	*Per cent.*
Jan. 16-17	72.5	0.10	0.03	1.35	1.48	71.0	97.9
17–18	72.5	.17	.03	1.40	1.60	70.9	97.8
Experiment No. 16.							
Jan. 18–19	72.5	.15	.04	2.13	2.32	70.2	96.8
19–20	72.5	.23	.02	1.62	1.87	70.6	97.4
Experiment No. 17.							
Jan. 20–21	72.5	.12	.04	1.53	1.69	70.8	97.7
21–22	72.5	....	.03	1.27	1.30	71.2	98.2
Total	435.0	.77	.19	9.30	10.26	424.7	....
Average per day	72.5	.13	.03	1.55	1.71	70.8	97.7

Balance of income and outgo of matter and energy.—The income and outgo of nitrogen, carbon, hydrogen, and energy in these experiments are shown in Tables XXIX to XXXII. It will be noticed that the subject was nearly in nitrogen and carbon equilibrium. The amount of water consumed was 1,382.5 grams, 600 of which were contained in drinking water and 782.5 in coffee infusion or water with which the alcohol was mixed. The agreement between the estimated energy of materials oxidized in the body and the heat actually determined in these experiments was very close, the variations being so small as to lie far within the limit of experimental error.

TABLE XXIX.—*Income and outgo of nitrogen and carbon—Metabolism experiments Nos. 15–17.*

Date and period.	Nitrogen.				Carbon.					
	(a) In food.	(b) In feces.	(c) In urine.	(d) Gain (+) or loss (−) a−(b+c).	(e) In food.	(f) In feces.	(g) In urine.	(h) In respiratory products.	(i) In alcohol eliminated.	(k) Gain (+) or loss (−) e−(f+g+h+i).
1899.										
Experiment No. 15.	*Gms.*	*Gms.*	*Gms.*	*Gms.*	*Gms.*	*Gms.*	*Gms.*	*Gms.*	*Gms.*	*Gms.*
Jan. 16–17, 7 a. m. to 7 a. m	17.4	0.8	15.1	+1.5	245.7	7.8	10.6	220.8	0.8	+ 5.7
17–18, 7 a. m. to 7 a. m	17.4	.8	16.2	+ .4	245.7	7.8	11.4	219.3	.8	+ 6.4
Total for 2 days	34.8	1.6	31.3	+1.9	491.4	15.6	22.0	440.1	1.6	+12.1
Average per day	17.4	.8	15.6	+1.0	245.7	7.8	11.0	220.0	.8	+ 6.1
Experiment No. 16.										
Jan. 18–19, 7 a. m. to 7 a. m	17.4	.8	15.2	+1.4	245.7	7.8	10.7	217.3	1.2	+ 8.7
19–20, 7 a. m. to 7 a. m	17.4	.8	15.7	+ .9	245.7	7.8	11.1	219.3	1.0	+ 6.5
Total for 2 days	34.8	1.6	30.9	+2.3	491.4	15.6	21.8	436.6	2.2	+15.2
Average per day	17.4	.8	15.5	+1.1	245.7	7.8	10.9	218.3	1.1	+ 7.6
Experiment No. 17.										
Jan. 20–21, 7 a. m. to 7 a. m	17.4	.8	15.7	+ .9	245.7	7.8	11.1	212.7	.9	+13.2
21–22, 7 a. m. to 7 a. m	17.4	.8	15.6	+1.0	245.7	7.8	11.0	216.3	.7	+ 9.9
Total for 2 days	34.8	1.6	31.3	+1.9	491.4	15.6	22.1	429.0	1.6	+23.1
Average per day	17.4	.8	15.6	+1.0	245.7	7.8	11.0	214.5	.8	+11.6
Total for 6 days	104.4	4.8	93.5	+6.1	1,474.2	46.8	65.9	1,305.7	5.4	+50.4
Average per day	17.4	.8	15.6	+1.0	245.7	7.8	11.0	217.6	.9	+ 8.4

TABLE XXX.—*Income and outgo of water and hydrogen—Metabolism experiments Nos. 15–17.*

Date and period.	Water. (a) In food.	(b) In drink.	(c) In feces.	(d) In urine.	(e) In respiratory products.	(f) Apparent loss $a+b-(c+d+e)$.
1899.						
Experiment No. 15.	*Grams.*	*Grams.*	*Grams.*	*Grams.*	*Grams.*	*Grams.*
Jan. 16–17, 7 a. m. to 7 a. m	1,095.2	1,382.5	35.9	1,426.4	910.9	+ 104.5
17–18, 7 a. m. to 7 a. m	1,095.2	1,382.5	35.9	2,197.1	966.7	− 722.0
Total for 2 days	2,190.4	2,765.0	71.8	3,623.5	1,877.6	− 617.5
Average per day	1,095.2	1,382.5	35.9	1,811.8	938.8	− 308.8
Experiment No. 16.						
Jan. 18–19, 7 a. m. to 7 a. m	1,095.2	1,382.5	35.9	1,813.9	947.1	− 319.2
19–20, 7 a. m. to 7 a. m	1,095.2	1,382.5	35.9	1,876.2	896.6	− 331.0
Total for 2 days	2,190.4	2,765.0	71.8	3,690.1	1,843.7	− 650.2
Average per day	1,095.2	1,382.5	35.9	1,845.0	921.9	− 325.1
Experiment No. 17.						
Jan. 20–21, 7 a. m. to 7 a. m	1,095.2	1,382.5	35.9	1,903.2	903.6	− 365.0
21–22, 7 a. m. to 7 a. m	1,095.2	1,382.5	35.9	2,026.6	879.4	− 464.2
Total for 2 days	2,190.4	2,765.0	71.8	3,929.8	1,783.0	− 829.2
Average per day	1,095.2	1,382.5	35.9	1,964.9	891.5	− 414.6
Total for 6 days	6,571.2	8,295.0	215.4	11,243.4	5,504.3	−2,096.9
Average per day	1,095.2	1,382.5	35.9	1,873.9	917.4	− 349.5

Date and period.	Hydrogen. (g) In food.	(h) In feces.	(i) In urine.	(k) In alcohol eliminated.	(l) Apparent gain $g-(h+i+k)$.	(m) Loss from water $f\div 9$.	(n) Total gain (+) or loss (−) $l+m$.
1899.							
Experiment No. 15.	*Grams.*	*Grams.*	*Grams.*	*Grams.*	*Grams.*	*Grams.*	*Grams.*
Jan. 16–17, 7 a. m. to 7 a. m	40.8	1.1	3.0	0.2	+ 36.5	+ 11.6	+48.1
17–18, 7 a. m. to 7 a. m	40.8	1.1	3.2	.2	+ 36.3	− 80.2	−43.9
Total for 2 days	81.6	2.2	6.2	.4	+ 72.8	− 68.6	+ 4.2
Average per day	40.8	1.1	3.1	.2	+ 36.4	− 34.3	+ 2.1
Experiment No. 16.							
Jan. 18–19, 7 a. m. to 7 a. m	40.8	1.1	3.0	.3	+ 36.4	− 35.5	+ .9
19–20, 7 a. m. to 7 a. m	40.8	1.1	3.1	.2	+ 36.4	− 36.8	− .4
Total for 2 days	81.6	2.2	6.1	.5	+ 72.8	− 72.3	+ .5
Average per day	40.8	1.1	3.1	.2	+ 36.4	− 36.1	+ .3
Experiment No. 17.							
Jan. 20–21, 7 a. m. to 7 a. m	40.8	1.1	3.1	.2	+ 36.4	− 40.5	− 4.1
21–22, 7 a. m. to 7 a. m	40.8	1.1	3.1	.2	+ 36.4	− 51.6	−15.2
Total for 2 days	81.6	2.2	6.2	.4	+ 72.8	− 92.1	−19.3
Average per day	40.8	1.1	3.1	.2	+ 36.4	− 46.1	− 9.7
Total for 6 days	244.8	6.6	18.5	1.3	+218.4	−233.0	−14.6
Average per day	40.8	1.1	3.1	.2	+ 36.4	− 38.8	− 2.4

TABLE XXXI.—*Gain or loss of protein ($N \times 6.25$), fat, and water—Metabolism experiments Nos. 15–17.*

Date and period.	(a) Nitrogen gained (+) or lost (−).	(b) Protein gained (+) or lost (−) $a \times 6.25$.	(c) Total carbon gained (+) or lost (−).	(d) Carbon in protein gained (+) or lost (−) $b \times 0.53$.	(e) Carbon in fat, etc., gained (+) or lost (−) $c-d$.	(f) Fat gained (+) or lost (−) $e \div 0.765$.
1899.						
Experiment No. 15.	*Grams.*	*Grams.*	*Grams.*	*Grams.*	*Grams.*	*Grams.*
Jan. 16–17, 7 a. m. to 7 a. m	+1.5	+ 9.4	+ 5.7	+ 5.0	+ 0.7	+ 0.9
17–18, 7 a. m. to 7 a. m	+ .4	+ 2.5	+ 6.4	+ 1.3	+ 5.1	+ 6.7
Total for 2 days	+1.9	+11.9	+12.1	+ 6.3	+ 5.8	+ 7.6
Average per day	+1.0	+ 6.0	+ 6.1	+ 3.2	+ 2.9	+ 3.8
Experiment No. 16.						
Jan. 18–19, 7 a. m. to 7 a. m	+1.4	+ 8.7	+ 8.7	+ 4.6	+ 4.1	+ 5.3
19–20, 7 a. m. to 7 a. m	+ .9	+ 5.6	+ 6.5	+ 3.0	+ 3.5	+ 4.6
Total for 2 days	+2.3	+14.3	+15.2	+ 7.6	+ 7.6	+ 9.9
Average per day	+1.1	+ 7.2	+ 7.6	+ 3.8	+ 3.8	+ 5.0
Experiment No. 17.						
Jan. 20–21, 7 a. m. to 7 a. m	+ .9	+ 5.6	+13.2	+ 3.0	+10.2	+13.4
21–22, 7 a. m. to 7 a. m	+1.0	+ 6.3	+ 9.9	+ 3.3	+ 6.6	+ 8.6
Total for 2 days	+1.9	+11.9	+23.1	+ 6.3	+16.8	+22.0
Average per day	+1.0	+ 6.0	+11.6	+ 3.2	+ 8.4	+11.0
Total for 6 days	+6.1	+38.1	+50.4	+20.2	+30.2	+39.5
Average per day	+1.0	+ 6.3	+ 8.4	+ 3.4	+ 5.0	+ 6.6

Date and period.	(g) Total hydrogen gained (+) or lost (−).	(h) Hydrogen in protein gained (+) or lost (−) $b \times 0.07$.	(i) Hydrogen in fat gained (+) or lost (−) $f \times 0.12$.	(k) Hydrogen in water, etc., gained (+) or lost (−) $g-(h+i)$.	(l) Water gained (+) or lost (−) $k \times 9$.
1899.					
Experiment No. 15.	*Grams.*	*Grams.*	*Grams.*	*Grams.*	*Grams.*
Jan. 16–17, 7 a. m. to 7 a. m	+48.1	+0.6	+0.1	+47.4	+426
17–18, 7 a. m. to 7 a. m	−43.9	+ .2	+ .8	−44.9	−404
Total for 2 days	+ 4.2	+ .8	+ .9	+ 2.5	+ 22
Average per day	+ 2.1	+ .4	+ .5	+ 1.3	+ 11
Experiment No. 16.					
Jan. 18–19, 7 a. m. to 7 a. m	+ .9	+ .6	+ .6	− .3	− 3
19–20, 7 a. m. to 7 a. m	− .4	+ .4	+ .6	− 1.4	− 12
Total for 2 days	+ .5	+1.0	+1.2	− 1.7	− 15
Average per day	+ .3	+ .5	+ .6	− .8	− 7
Experiment No. 17.					
Jan. 20–21, 7 a. m. to 7 a. m	− 4.1	+ .4	+1.6	− 6.1	− 55
21–22, 7 a. m. to 7 a. m	−15.2	+ .4	+1.0	−16.6	−149
Total for 2 days	−19.3	+ .8	+2.6	−22.7	−204
Average per day	− 9.7	+ .4	+1.3	−11.4	−102
Total for 6 days	−14.6	+2.6	+4.7	−21.9	−197
Average per day	− 2.4	+ .4	+ .8	− 3.6	− 33

TABLE XXXII.—*Income and outgo of energy—Metabolism experiments Nos. 15–17.*

Date and period.	(a) Heat of combustion of food eaten.	(b) Heat of combustion of feces.	(c) Heat of combustion of urine.	(d) Heat of combustion of alcohol eliminated.	(e) Estimated heat of combustion of protein gained (+) or lost (−).	(f) Estimated heat of combustion of fat gained (+) or lost (−).	(g) Estimated energy of material oxidized in the body $a-(b+c+d+e+f)$.	(h) Heat determined.	(i) Heat determined greater (+) or less (−) than estimated, $h-g$.	(k) Heat determined greater (+) or less (−) than estimated, $i \div g$.
1899.										
Experiment No. 15.	*Calories.*	*Calories.*	*Calories.*	*Calories.*	*Calories.*	*Calories.*	*Calories.*	*Calories.*	*Calories.*	*Per cent.*
Jan. 16–17, 7 a. m. to 7 a. m.	2,653	88	123	10	+ 54	+ 8	2,370	2,382	+12	+0.5
17–18, 7 a. m. to 7 a. m.	2,653	88	132	11	+ 15	+ 63	2,344	2,343	− 1	......
Total for 2 days	5,306	176	255	21	+ 69	+ 71	4,714	4,725	+11	......
Average per day	2,653	88	128	11	+ 34	+ 35	2,357	2,362	+ 5	+ .2
Experiment No. 16.										
Jan. 18–19, 7 a. m. to 7 a. m.	2,653	88	124	16	+ 50	+ 50	2,325	2,308	−17	− .7
19–20, 7 a. m. to 7 a. m.	2,653	88	128	15	+ 32	+ 43	2,347	2,356	+ 9	+ .4
Total for 2 days	5,306	176	252	31	+ 82	+ 93	4,672	4,664	− 8	......
Average per day	2,653	88	126	15	+ 41	+ 47	2,336	2,332	− 4	− .2
Experiment No. 17.										
Jan. 20–21, 7 a. m. to 7 a. m.	2,653	88	128	12	+ 32	+126	2,267	2,248	−19	− .8
21–22, 7 a. m. to 7 a. m.	2,653	88	128	9	+ 36	+ 81	2,311	2,304	− 7	− .3
Total for 2 days	5,306	176	256	21	+ 68	+207	4,578	4,552	−26	......
Average per day	2,653	88	128	10	+ 34	+104	2,289	2,276	−13	− .6
Total for 6 days	15,918	528	763	73	+219	+371	13,964	13,941	−23	......
Average per day	2,653	88	127	12	+ 37	+ 62	2,327	2,323	− 4	− .2

EXPERIMENTS NOS. 18–21.—REST. NOS. 18–20 WITH ALCOHOL DIET.

Subject.—A. W. S., a physicist, who was associated with these investigations. He was 25 years of age and averaged about 70 kilograms (154 pounds) in weight.

Occupation during experiment.—Reading, writing, etc., with as little mental and muscular activity as practicable.

Duration.—The preliminary period began with breakfast, February 2, 1899, and continued 4 days. On the evening of the fourth day the subject entered the calorimeter, and experiment No. 18, the first of the series, commenced at 7 o'clock the following morning, February 6, and continued 2 days. It was followed by Nos. 19 and 20 of 2 days each. A fourth experiment, elsewhere described,[a] No. 21, in which the alcohol was omitted from the diet. followed No. 20 immediately and continued 3 days. The subject thus spent 10 nights and 9 days in the chamber.

Diet.—Ordinary food furnishing 97 grams of protein and 2,264 calories of energy per day, in addition to 72.5 grams of absolute alcohol furnishing 512 calories of energy; making the total energy of the diet 2,776 calories per day. In experiment No. 18 the alcohol was furnished in ordinary commercial alcohol, in experiment No. 19 in whisky, and in experiment No. 20 in brandy. The plan of the experiment was thus practically the same as that of the previous series of experiments, Nos. 15–17. The alcohol was taken as usual in 6 doses, 3 with the meals and the other 3 between meals and upon retiring.

In experiment No. 18, 775.2 grams of coffee infusion were sweetened with 45 grams of sugar, and 79.8 grams of 90.9 per cent commercial alcohol were then added. In experiment No. 19, 158.3 grams of whisky containing 45.8 per cent alcohol by weight was added to 696.7

[a] U. S. Dept. Agr., Office of Experiment Stations. Bul. 109.

grams of water, sweetened with 45 grams of sugar. In experiment No. 20, 143.8 grams of brandy containing 50.4 per cent alcohol by weight was added to 711.2 grams of water, sweetened with 45 grams of sugar. It will be noticed that the coffee infusion was used only in the first of the series of experiments. The reason for use of the coffee infusion was to cover up the taste of the commercial ethyl alcohol, which was somewhat obnoxious to the subject.

The kinds and quantities of food served at each meal and the quantity of drink at different periods were as follows:

Diet in metabolism experiments Nos. 18–21.

FOOD.

	Breakfast.	Dinner.	Supper.	Total.
	Grams.	*Grams.*	*Grams.*	*Grams.*
Beef	55	105	....	160
Butter	7	10	13	30
Milk, whole	250	175	325	750
Bread	55	100	155	310
Parched cereal	30	....	....	30
Sugar	45	....	....	[a]45

[a]Used with the coffee infusion or water and alcohol in experiments 18–20.

DRINK.

Time.	Experiment 18.		Experiment 19.		Experiment 20.		Experiment 21.
	Alcohol and sweetened coffee infusion.[a]	Water.	Whisky and sweetened water.[a]	Water.	Brandy and sweetened water.[a]	Water.	Water.
	Grams.	*Grams.*	*Grams.*	*Grams.*	*Grams.*	*Grams.*	*Grams.*
Breakfast	300	....	300	....	300	....	300
10 a. m.	....	200	....	200	....	200	200
Dinner	300	....	300	....	300	....	300
3.30 p. m.	....	200	....	200	....	200	200
Supper	300	....	300	....	300	....	300
10.30 p. m.	....	200	....	200	....	200	200
	[a]900	600	[a]900	600	[a]900	600	1,500

[a]Contained 72.5 grams alcohol and 45 grams sugar.

Daily routine.—The general plan of the experiment was practically the same as in the previous experiments, and is shown in the following schedule:

Daily programme—Metabolism experiments Nos. 18–20.

7 a. m	Rise, pass urine, weigh self stripped and dressed, weigh absorbers.	6 p. m	Supper.
7.45 a. m	Breakfast, drink 200 grams water.	7 p. m	Pass urine.
1 p. m	Pass urine.	10.30 p. m	Pass urine, weigh self stripped, take cap off food aperture; retire, sleep until 7 a. m.
1.15 p. m	Dinner.		

The statistics of the diary kept by the subject are summarized in Table XXXIII.

TABLE XXXIII.—*Summary of diary—Metabolism experiments Nos. 18–20.*

Date and time.	Weight without clothes.	Pulse rate per minute.	Temperature.	Hygrometer.	
				Dry bulb.	Wet bulb.
1899.	*Kilograms.*		°*F.*	°*C.*	°*C.*
Feb. 6, 7 a. m	69.15	72	97.3	19.60	14.80
6, 12.50 p. m				19.80	15.95
6, 6.50 p. m				19.80	15.40
6, 8.10 p. m	69.90	78	98.5		
7, 7 a. m	69.36	66	97.3	19.90	15.60
7, 12 m				19.60	15.20
7, 7.10 p. m				19.80	15.80
7, 10.26 p. m	69.60	68	97.5	19.60	15.60
8, 7 a. m	69.10	73	96.8	20.00	15.10
8, 12.46 p. m				19.80	15.45
8, 6.45 p. m				19.75	15.20
8, 10.08 p. m	70.00	67	96.8	19.60	14.80
9, 7 a. m	69.50	69	97.2	20.00	15.00
9, 12.46 p. m				19.70	15.00
9, 6.50 p. m				19.70	14.80
9, 10.08 p. m	69.80	85	97.8	19.70	15.40
10, 7 a.m	69.55	62	97.1	19.70	15.00
10, 12.45 p. m				19.65	14.95
10, 6.53 p. m				19.75	15.05
10, 10.18 p. m	70.15	66	97.0	19.80	15.30
11, 7 a.m	69.70	78	97.4	19.80	14.90
11, 12.42 p. m				19.70	15.40
11, 6.50 p. m				19.70	14.85
11, 10.30 p. m	70.05	81	97.5	19.70	15.00
12, 7 a. m	69.48	70	97.8	19.80	15.15

Detailed statistics of income and outgo.—The usual statistics of income and outgo of matter and energy are shown in Tables XXXIV to XLVI, which follow. The diet was the same during the series of experiments Nos. 18–20, except in the form of alcohol taken. It supplied 97 grams of protein and 2,776 calories of energy per day. In experiment No. 21, which immediately followed, the diet was the same, with the exception that no alcohol was administered, so that the total energy of the food was only 2,264 calories.

No separation of the feces was obtained between the beginning of the preliminary period and the end of experiment No. 21, in which the subject had what may be called the basal ration without the alcohol. It was necessary, therefore, to assume a uniform amount of feces from the food from day to day. While this may introduce a slight error in the results of the 3 experiments with alcohol, Nos. 18–20, such error can hardly be large enough to affect seriously the computed results of the experiments.

TABLE XXXIV.—*Weight, composition, and heat of combustion of foods—Metabolism experiments Nos. 18–21.*

Laboratory No.	Food material.	Weight per day.	Water.	Protein.	Fat.	Carbohydrates.	Nitrogen.	Carbon.	Hydrogen.	Heat of combustion.
		Grams.	*Grams.*	*Grams.*	*Grams.*	*Grams.*	*Grams.*	*Grams.*	*Grams.*	*Calories.*
3022	Beef	160	106.7	44.6	4.2		7.14	26.51	4.06	292
3020	Butter	30	2.6	.4	26.3		.06	19.87	3.16	245
3024	Milk, whole	750	649.5	24.0	33.0	37.5	3.83	52.72	7.05	587
2968	Bread	310	129.3	24.5	8.7	143.5	3.94	84.72	12.74	840
3004	Cereal, parched	30	1.8	3.4	.2	24.1	.55	12.42	1.85	122
	Sugar	45				45.0		18.95	2.92	178
	Total Feb. 12 to 14	1,325	889.9	96.9	72.4	250.1	15.52	215.19	31.78	2,264
	Alcohol	72.5						37.82	9.46	512
	Total Feb. 6 to 12						15.52	253.01	41.24	2,776

TABLE XXXV.—*Weight, composition, and heat of combustion of feces—Metabolism experiments Nos. 18–21.*

Laboratory No.		Weight.	Water.	Protein.	Fat.	Carbohydrates.	Nitrogen.	Carbon.	Hydrogen.	Heat of combustion.
		Grams.	*Grams.*	*Grams.*	*Grams.*	*Grams.*	*Grams.*	*Grams.*	*Grams.*	*Calories.*
3033	Total for 13 days	831.7	603.8	84.0	52.4	52.4	13.47	116.69	16.13	1,307
	Average per day	63.9	46.4	6.5	4.0	4.0	1.04	8.98	1.24	100

In these investigations the elimination of nitrogen in the urine on the first day inside the apparatus has frequently been larger than that of the preceding and following days. Sometimes this increase occurs 1 or 2 days before the subject enters the respiration chamber. On the 4 days of the preliminary period preceding this series of experiments the nitrogen in the urine amounted to 12.2, 16, 19 and 16.4 grams, respectively On the first day of experiment No. 18 the nitrogen in the urine amounted to 17.4 grams, but it dropped to 15.4 grams on the second day, and varied between 13.9 and 14.7 on subsequent days. In experiment No. 21, when the energy of the diet was reduced, the excretion of nitrogen again increased. The elimination of nitrogen with and without alcohol has been already referred to.

Table XXXVI gives the detailed statistics of the quantity of urine and its nitrogen content in the successive 6-hour periods of this series of experiments. The statistics for experiment No. 21, in which no alcohol was given, show the total quantity of urine and nitrogen for the individual days, but not for individual periods. These daily amounts are given for the sake of comparison with those of experiments 18–20.

TABLE XXXVI.—*Amount, specific gravity, and nitrogen of urine by 6-hour periods—Metabolism experiments Nos. 18–20.*[a]

Date.	Period.	Amount.	Specific gravity.	Nitrogen.	
	Experiment No. 18.	*Grams.*		*Per cent.*	*Grams.*
1899. Feb. 6–7	7 a. m. to 1 p. m.	325.4	1.022	1.47	4.78
	1 p. m. to 7 p. m.	441.7	1.018	1.21	5.34
	7 p. m. to 1 a. m.	265.5	1.027	1.14	3.03
	1 a. m. to 7 a. m.	299.8	1.021	1.41	4.23
	Total	1,332.4			17.38
	Total by composite	1,332.4	1.019	1.31	17.45
7–8	7 a. m. to 1 p. m.	890.7	1.009	.54	4.81
	1 p. m. to 7 p. m.	690.3	1.011	.71	4.90
	7 p. m. to 1 a. m.	194.4	1.017	1.08	2.10
	1 a. m. to 7 a. m.	225.9	1.024	1.59	3.59
	Total	2,001.3			15.40
	Total by composite	2,001.3	1.013	.78	15.61
	Experiment No. 19.				
8–9	7 a. m. to 1 p. m.	609.8	1.012	.70	4.27
	1 p. m. to 7 p. m.	387.6	1.018	1.07	4.14
	7 p. m. to 1 a. m.	155.8	1.020	1.36	2.12
	1 a. m. to 7 a. m.	337.7	1.017	1.23	4.15
	Total	1,490.9			14.68
	Total by composite	1,490.9	1.015	.97	14.46
9–10	7 a. m. to 1 p. m.	569.8	1.011	.72	4.10
	1 p. m. to 7 p. m.	664.7	1.012	.66	4.39
	7 p. m. to 1 a. m.	262.8	1.013	.87	2.29
	1 a. m. to 7 a. m.	237.5	1.020	1.44	3.42
	Total	1,734.8			14.20
	Total by composite	1,734.8	1.013	.82	14.22

[a] No. 21 included for comparison.

TABLE XXXVI.—*Amount, specific gravity, and nitrogen of urine by 6-hour periods, etc.*—Continued.

Date.	Period.	Amount	Specific gravity.	Nitrogen.	
1899.	*Experiment No. 20.*	*Grams.*		*Per cent.*	*Grams.*
10–11	7 a. m. to 1 p. m.	715. 1	1. 008	0. 55	3. 93
	1 p. m. to 7 p. m.	445. 1	1. 016	. 87	3. 87
	7 p. m. to 1 a. m.	270. 9	1. 012	. 78	2. 11
	1 a. m. to 7 a. m.	265. 6	1. 021	1. 49	3. 96
	Total	1, 696. 7			13. 87
	Total by composite	1, 696. 7	1. 013	. 82	13. 91
11–12	7 a. m. to 1 p. m.	611. 1	1. 011	. 66	4. 03
	1 p. m. to 7 p. m.	703. 7	1. 011	. 63	4. 43
	7 p. m. to 1 a. m.	360. 8	1. 012	. 70	2. 52
	1 a. m. to 7 a. m.	264. 5	1. 020	1. 29	3. 41
	Total	1, 940. 1			14. 39
	Total by composite	1, 940. 1	1. 013	. 73	14. 16
	Total for 6 days, by periods	10, 196. 2			89. 92
6–11	Total by composite	10, 196. 2	1. 0135	. 88	89. 69
	Experiment No. 21.				
12–13	Total, 7 a. m. to 7 a. m.	1, 680. 9			14. 50
13–14	Total, 7 a. m. to 7 a. m.	1, 748. 1			16. 15
14–15	Total, 7 a. m. to 7 a. m.	1, 965. 3			15. 44
12, 13, 14	Total for 3 days	5, 394. 3			46. 09

TABLE XXXVII.—*Daily elimination of carbon, hydrogen, water, and energy in urine—Metabolism experiments Nos. 18–20.*[a]

Date.	Amount.	Carbon.		Hydrogen.		Water.		Heat of combustion.	
								Per gram.	Total.
1899.									
Experiment No. 18.	*Grams.*	*Per ct.*	*Grams.*	*Per ct.*	*Grams.*	*Per ct.*	*Grams.*	*Calories.*	*Calories.*
Feb. 6–7	1, 332. 4		11. 04		3. 55		1, 269. 3		130
7–8	2, 001. 3		9. 78		3. 14		1, 945. 4		115
Experiment No. 19.									
Feb. 8–9	1, 490. 9		9. 32		2. 99		1, 437. 6		110
9–10	1, 734. 8		9. 01		2. 90		1, 683. 3		106
Experiment No. 20.									
Feb. 10–11	1, 696. 7		8. 81		2. 83		1, 646. 4		104
11–12	1, 940. 1		9. 14		2. 94		1, 887. 9		108
Total, 6 days	10, 196. 2	0. 56	57. 10	0. 18	18. 35	96. 8	9, 869. 9	0. 066	673
Experiment No. 21.									
Feb. 12–13	1, 680. 9		10. 18		2. 89		1, 628. 3		119
13–14	1, 748. 1		11. 34		3. 21		1, 689. 5		132
14–15	1, 965. 3		10. 85		3. 07		1, 909. 3		127
Total, 3 days	5, 394. 3	. 60	32. 37	. 17	9. 17	96. 9	5, 227. 1	. 070	378

[a] No. 21 summarized for comparison.

The details of the measurements of carbon dioxid and water in the ventilating air current are shown in Tables XXXVIII to XL, which follow. The total amounts of carbon dioxid and water eliminated each day in Experiment No. 21 are also added for comparison.

TABLE XXXVIII.—*Comparison of residual amounts of carbon dioxid and water in the chamber at the beginning and end of each period, and the corresponding gain or loss—Metabolism experiments Nos. 18–20.*

Date.	End of period.	Carbon dioxid. Total amount in chamber.	Carbon dioxid. Gain (+) or loss (−) over preceding period.	Water. Total amount of vapor remaining in chamber.	Water. Gain (+) or loss (−) over preceding period.	Water. Change in weight of absorbers. Gain (+) or loss (−).	Water. Total amount gained (+) or lost (−) during the period.
1899.		*Grams.*	*Grams.*	*Grams.*	*Grams.*	*Grams.*	*Grams.*
Feb. 6	7 a. m.	29	....	35.0	....	....	....
6–7	1 p. m.	42.6	+13.6	46.4	+11.4	+ 2	+13.4
	7 p. m.	41.3	− 1.3	42.1	− 4.3	+ 2	− 2.3
	1 a. m.	37.2	− 4.1	46.2	+ 4.1	+ 1	+ 5.1
	7 a. m.	31.5	− 5.7	39.3	− 6.9	+ 1	− 5.9
	Total	....	+ 2.5	....	+ 4.3	+ 6	+10.3
7–8	1 p. m.	39.6	+ 8.1	40.8	+ 1.5	− 1	+ .5
	7 p. m.	31.3	− 8.3	44.5	+ 3.7	− 1	+ 2.7
	1 a. m.	30.1	− 1.2	41.0	− 3.5	− 1	− 4.5
	7 a. m.	26.4	− 3.7	35.6	− 5.4	− 1	− 6.4
	Total	....	− 5.1	....	− 3.7	− 4	− 7.7
8–9	1 p. m.	39.2	+12.8	41.8	+ 6.2	+ 2	+ 8.2
	7 p. m.	38.9	− .3	41.1	− .7	+ 2	+ 1.3
	1 a. m.	26.8	−12.1	38.0	− 3.1	+ 1	− 2.1
	7 a. m.	26.3	− .5	33.6	− 4.4	+ 1	− 3.4
	Total	....	− .1	....	− 2.0	+ 6	+ 4.0
9–10	1 p. m.	37.5	+11.2	39.3	+ 5.7	− 1	+ 4.7
	7 p. m.	40.1	+ 2.6	38.2	− 1.1	− 1	− 2.1
	1 a. m.	30.3	− 9.8	39.7	+ 1.5	− 1	+ .5
	7 a. m.	29.9	− 0.4	36.4	− 3.3	− 2	− 5.3
	Total	....	+ 3.6	....	+ 2.8	− 5	− 2.2
10–11	1 p. m.	37.5	+ 7.6	39.1	+ 2.7	+ 3	+ 5.7
	7 p. m.	42.8	+ 5.3	40.9	+ 1.8	+ 2	+ 3.8
	1 a. m.	30.4	−12.4	39.3	− 1.6	+ 2	+ .4
	7 a. m.	35.5	+ 5.1	36.1	− 3.2	+ 2	− 1.2
	Total	....	+ 5.6	....	− .3	+ 9	+ 8.7
11–12	1 p. m.	40.8	+ 5.3	43.5	+ 7.4	....	+ 7.4
	7 p. m.	42.8	+ 2.0	39.3	− 4.2	....	− 4.2
	1 a. m.	30.9	−11.9	41.6	+ 2.3	....	+ 2.3
	7 a. m.	32.7	+ 1.8	38.1	− 3.5	....	− 3.5
	Total	....	− 2.8	....	+ 2.0	....	+ 2.0

TABLE XXXIX.—*Record of carbon dioxid in ventilating air current—Metabolism experiments Nos. 18–20*[a].

Date.	Period.	(a) Ventilation. Number of liters of air.	Carbon dioxid. In incoming air. (b) Per liter.	Carbon dioxid. In incoming air. (c) Total, a×b.	Carbon dioxid. (d) In outgoing air.	Carbon dioxid. (e) Total excess in outgoing air, d—c.	Carbon dioxid. (f) Correction for amount remaining in chamber.	Carbon dioxid. (g) Corrected amount exhaled by subject, e+f.	(h) Total weight of carbon exhaled, g×3/11.
	Experiment No. 18.								
1899.		*Liters.*	*Mg.*	*Grams.*	*Grams.*	*Grams.*	*Grams.*	*Grams.*	*Grams.*
Feb. 6–7	7 a. m.–1 p. m.	26,069	0.569	14.8	254.9	240.1	+13.6	253.7	69.2
	1 p. m.–7 p. m.	25,745	.511	13.2	232.7	219.5	− 1.3	218.2	59.5
	7 p. m.–1 a. m.	26,362	.566	14.9	230.8	215.9	− 4.1	211.8	57.7
	1 a. m.–7 a. m.	27,245	[b].570	15.5	160.3	144.8	− 5.7	139.1	38.0
	Total	105,421	....	58.4	878.7	820.3	+ 2.5	822.8	224.4
7–8	7 a. m.–1 p. m.	25,795	.575	14.8	239.6	224.8	+ 8.1	232.9	63.5
	1 p. m.–7 p. m.	25,908	.531	13.7	236.7	223.0	− 8.3	214.7	58.6
	7 p. m.–1 a. m.	26,924	.554	14.9	216.6	201.7	− 1.2	200.5	54.7
	1 a. m.–7 a. m.	27,122	.576	15.6	157.1	141.5	− 3.7	137.8	37.5
	Total	105,749	....	59.0	850.0	791.0	− 5.1	785.9	214.3
	Experiment No. 19.								
8–9	7 a. m.–1 p. m.	26,792	.562	15.1	223.9	208.8	+12.8	221.6	60.5
	1 p. m.–7 p. m.	26,010	.616	16.0	224.0	208.0	− .3	207.7	56.6
	7 p. m.–1 a. m.	27,593	.554	15.3	210.7	195.4	−12.1	183.3	50.0
	1 a. m.–7 a. m.	27,999	.552	15.5	159.4	143.9	− .5	143.4	39.1
	Total	108,394	....	61.9	818.0	756.1	− .1	756.0	206.2
9–10	7 a. m.–1 p. m.	26,388	.554	14.6	223.9	209.3	+11.2	220.5	60.2
	1 p. m.–7 p. m.	26,150	.578	15.1	211.0	195.9	+ 2.6	198.5	54.1
	7 p. m.–1 a. m.	27,647	.579	16.0	225.7	209.7	− 9.8	199.9	54.5
	1 a. m.–7 a. m.	28,015	.550	15.4	156.1	140.7	− .4	140.3	38.3
	Total	108,200	....	61.1	816.7	755.6	+ 3.6	759.2	207.1
	Experiment No. 20.								
10–11	7 a. m.–1 p. m.	25,750	.561	14.4	223.8	209.4	+ 7.6	217.0	59.2
	1 p. m.–7 p. m.	26,228	.608	16.0	217.6	201.6	+ 5.3	206.9	56.4
	7 p. m.–1 a. m.	27,422	.575	15.8	227.0	211.2	−12.4	198.8	54.2
	1 a. m.–7 a. m.	28,046	.562	15.7	173.0	157.3	+ 5.1	162.4	44.3
	Total	107,446	....	61.9	841.4	779.5	+ 5.6	785.1	214.1
11–12	7 a. m.–1 p. m.	26,132	.595	15.6	240.8	225.2	+ 5.3	230.5	62.8
	1 p. m.–7 p. m.	26,157	.600	15.7	222.3	206.6	+ 2.0	208.6	56.9
	7 p. m.–1 a. m.	27,966	.562	15.7	235.4	219.7	−11.9	207.8	56.7
	1 a. m.–7 a. m.	28,443	.573	16.3	168.0	151.7	+ 1.8	153.5	41.9
	Total	108,698	....	63.3	866.5	803.2	− 2.8	800.4	218.3
	Experiment No. 21.								
12–13	7 a. m.–7 a. m.	109,063	....	62.7	857.1	794.4	− 5.3	789.1	215.2
13–14	7 a. m.–7 a. m.	109,164	....	128.3	913.9	785.6	+ 1.3	786.9	214.6
14–15	7 a. m.–7 a. m.	107,982	....	65.2	884.2	819.0	− 3.0	816.0	222.5

[a] No. 21 included for comparison.
[b] Sample lost; carbon dioxid assumed to be the same in amount as the average in preceding and following periods.

TABLE XL.—*Record of water in ventilating air current—Metabolism experiments Nos 18–20.* [a]

Date.	Period.	(*a*) Ventilation. Number of liters of air.	Water in incoming air. (*b*) Per liter.	Water in incoming air. (*c*) Total, $a \times b$.	Water in outgoing air. (*d*) Amount condensed in freezers.	Water in outgoing air. (*e*) Amount not condensed in freezers.	Water in outgoing air. (*f*) Total, $d + e$.	(*g*) Total excess water in outgoing air, $f - c$.	(*h*) Correction for water remaining in chamber.	(*i*) Total water of respiration and perspiration, $g + h$.
	Experiment No. 18.									
1899.		*Liters.*	*Mg.*	*Grams.*	*Grams.*	*Grams.*	*Grams.*	*Grams.*	*Grams.*	*Grams.*
Feb. 6–7	7 a. m.–1 p. m.	26,069	0.825	21.5	200.5	45.0	245.5	224.0	+13.4	237.4
	1 p. m.–7 p. m.	25,745	.769	19.8	201.8	37.4	239.2	219.4	− 2.3	217.1
	7 p. m.–1 a. m.	26,362	.799	21.1	210.5	41.2	251.7	230.6	+ 5.1	235.7
	1 a. m.–7 a. m.	27,245	.812	22.1	196.9	37.3	234.2	212.1	− 5.9	206.2
	Total	105.421	......	84.5	809.7	160.9	970.6	886.1	+10.3	896.4
7–8	7 a. m.–1 p. m.	25,795	.825	21.3	192.2	38.1	230.3	209.0	+ .5	209.5
	1 p. m.–7 p. m.	25,908	.820	21.2	212.0	37.2	249.2	228.0	+ 2.7	230.7
	7 p. m.–1 a. m.	26,924	.790	21.3	213.0	40.2	253.2	231.9	− 4.5	227.4
	1 a. m.–7 a. m.	27,122	.797	21.6	193.8	37.9	231.7	210.1	− 6.4	203.7
	Total	105,749	......	85.4	811.0	153.4	964.4	879.0	− 7.7	871.3
	Experiment No. 19.									
8–9	7 a. m.–1 p. m.	26,792	.812	21.8	195.3	38.2	233.5	211.7	+ 8.2	219.9
	1 p. m.–7 p. m.	26,010	.811	21.1	195.1	36.1	231.2	210.1	+ 1.3	211.4
	7 p. m.–1 a. m.	27,593	.775	21.4	191.6	41.8	233.4	212.0	− 2.1	209.9
	1 a. m.–7 a. m.	27,999	.719	20.1	184.4	40.0	224.4	204.3	− 3.4	200.9
	Total	108,394	......	84.4	766.4	156.1	922.5	838.1	+ 4.0	842.1
9–10	7 a. m.–1 p. m.	26,388	.738	19.5	184.3	35.8	220.1	200.6	+ 4.7	205.3
	1 p. m.–7 p. m.	26,150	.747	19.5	173.6	34.6	208.2	188.7	− 2.1	186.6
	7 p. m.–1 a. m.	27,647	.758	20.9	192.4	44.7	237.1	216.2	+ .5	216.7
	1 a. m.–7 a. m.	28,015	.685	19.2	185.7	35.5	221.2	202.0	− 5.3	196.7
	Total	108,200	......	79.1	736.0	150.6	886.6	807.5	− 2.2	805.3
	Experiment No. 20.									
10–11	7 a. m.–1 p. m.	25,750	.697	17.9	178.6	34.9	213.5	195.6	+ 5.7	201.3
	1 p. m.–7 p. m.	26,228	.703	18.4	194.6	35.4	230.0	211.6	+ 3.8	215.4
	7 p. m.–1 a. m.	27,422	.645	17.7	195.6	42.7	238.3	220.6	+ .4	221.0
	1 a. m.–7 a. m.	28,046	.555	15.5	179.3	36.0	215.3	199.8	− 1.2	198.6
	Total	107,446	......	69.5	748.1	149.0	897.1	827.6	+ 8.7	836.3
11–12	7 a. m.–1 p. m.	26,132	.559	14.6	191.2	35.8	227.0	212.4	+ 7.4	219.8
	1 p. m.–7 p. m.	26,157	.645	16.9	188.5	35.7	224.2	207.3	− 4.2	203.1
	7 p. m.–1 a. m.	27,966	.697	19.5	193.8	45.6	239.4	219.9	+ 2.3	222.2
	1 a. m.–7 a. m.	28,443	.723	20.6	189.1	37.5	226.6	206.0	− 3.5	202.5
	Total	108,698	......	71.6	762.6	154.6	917.2	845.6	+ 2.0	847.6
	Experiment No. 21.									
12–13	7 a. m.–7 a. m.	109,063	......	81.1	755.4	150.1	905.5	824.4	− 3.1	821.3
13–14	7 a. m.–7 a. m.	109,064	......	84.9	795.9	149.4	945.3	860.4	− 2.0	858.4
14–15	7 a. m.–7 a. m.	107,982	......	84.3	833.5	146.7	980.2	895.9	+ 1.7	897.6

[a] No. 21 included for comparison.

The calorimetric measurements for experiments 18–20 are given in detail, and those for experiment 21 summarized, in Table XLI.

TABLE XLI.—*Summary of calorimetric measurements—Metabolism experiments Nos. 18–20.*[a]

Date.	Period.	(a) Heat measured in terms of $C°_{20}$.	(b) Change of temperature of calorimeter.	(c) Capacity correction of calorimeter, $b \times 60$.	(d) Correction due to temperature of food and dishes.	(e) Water vaporized equals total amount exhaled, less amount condensed in chamber.	(f) Heat used in vaporization of water, $e \times 0.592$.	(g) Total heat determined, $a+c+d+f$.
	Experiment No. 18.							
1899.		*Calories.*	*Degrees.*	*Calories.*	*Calories.*	*Grams.*	*Calories.*	*Calories.*
Feb. 6–7	7 a. m. to 1 p. m	713.7	....	....	+ 5.5	235.4	139.4	858.6
	1 p. m. to 7 p. m	522.7	+0.09	+ 5.40	+ 8.5	215.1	127.3	663.9
	7 p. m. to 1 a. m	491.0	− .02	− 1.20	....	234.7	139.0	628.8
	1 a. m. to 7 a. m	308.5	− .05	− 3.00	....	205.2	121.5	427.0
	Total	2,035.9	+ .02	+ 1.20	+14.0	890.4	527.2	2,578.3
7–8	7 a. m. to 1 p. m	599.4	+ .05	+ 3.00	+ 8.2	210.5	124.6	735.2
	1 p. m. to 7 p. m	525.6	+ .03	+ 1.80	+ 9.3	231.7	137.2	673.9
	7 p. m. to 1 a. m	475.1	+ .14	+ 8.40	....	228.4	135.2	618.7
	1 a. m. to 7 a. m	262.9	− .25	−15.00	....	204.7	121.2	369.1
	Total	1,863.0	− .03	− 1.80	+17.5	875.3	518.2	2,396.9
	Experiment No. 19.							
8–9	7 a. m. to 1 p. m	540.0	+ .11	+ 6.60	+ 5.1	217.9	129.0	680.7
	1 p. m. to 7 p. m	497.2	+ .01	+ .60	+ 7.5	209.4	124.0	629.3
	7 p. m. to 1 a. m	432.3	− .03	− 1.80	....	208.9	123.7	554.2
	1 a. m. to 7 a. m	296.4	+ .03	+ 1.80	....	199.9	118.3	416.5
	Total	1,765.9	+ .12	+ 7.20	+12.6	836.1	495.0	2,280.7
9–10	7 a. m. to 1 p. m	528.4	+ .04	+ 2.40	+ 6.2	206.3	122.1	659.1
	1 p. m. to 7 p. m	446.3	− .05	− 3.00	+ 9.4	187.6	111.1	563.8
	7 p. m. to 1 a. m	470.3	+ .06	+ 3.60	....	217.7	128.9	602.8
	1 a. m. to 7 a. m	335.3	− .02	− 1.20	....	198.7	117.6	451.7
	Total	1,780.3	+ .03	+ 1.80	+15.6	810.3	479.7	2,277.4
	Experiment No. 20.							
10–11	7 a. m. to 1 p. m	522.9	+ .01	+ .60	+ 6.1	198.3	117.4	647.0
	1 p. m. to 7 p. m	483.4	+ .02	+ 1.20	+ 7.8	213.4	126.3	618.7
	7 p. m. to 1 a. m	477.7	− .03	− 1.80	....	219.0	129.6	605.5
	1 a. m. to 7 a. m	310.0	....	....	....	196.6	116.4	426.4
	Total	1,794.0	0.0	0.0	+13.9	827.3	489.7	2,297.6
11–12	7 a. m. to 1 p. m	549.1	+ .01	+ .60	+11.9	219.8	130.0	691.6
	1 p. m. to 7 p. m	461.1	− .02	− 1.20	+10.4	203.1	120.3	590.6
	7 p. m. to 1 a. m	460.2	+ .06	+ 3.60	....	222.2	131.6	595.4
	1 a. m. to 7 a. m	312.9	− .04	− 2.40	....	202.5	119.9	430.4
	Total	1,783.3	+ .01	+ .60	+22.3	847.6	501.8	2,308.0
	Experiment No. 21.							
12–13	7 a. m. to 7 a. m	1,718.8	− .02	− 1.20	+22.4	821.3	486.2	2,226.2
13–14	7 a. m. to 7 a. m	1,737.4	− .02	− 1.20	+16.9	860.4	509.4	2,262.5
14–15	7 a. m. to 7 a. m	1,801.5	+ .03	+ 1.80	+13.8	896.6	530.8	2,347.9

[a] No. 21 included for comparison.

The determinations of reducing material in the ventilating air current were made according to the method followed in the preceding experiments (see p. 258). The analytical data are shown in Table XLII. It will be noticed that the amount of reducing material, reckoned as alcohol, found in the air current on the first day of the series of experiments, February 6–7, is considerably larger than on the 3 days following. This may be due in part to the fact that the subject had taken with him into the chamber an atomizer containing an alcoholic solution of eucalyptol, of which reagent, however, only a very small amount was used on the first day, and none thereafter. It will also be observed that the amount of reducing material in the air current during the 3 days of experiment No. 21, in which alcohol did not form a part of the diet, was considerable. Attention has already been called to the fact that what is reckoned as alcohol in the air current consists to a greater or less degree of reducing matter ordinarily present in the respired air, whether the subject consumed alcohol or not. Later experiments indicate that this amount of reducing material may be equivalent to as much as 0.4 of a gram of alcohol per day (see experiments 26, 28, and 30 beyond). That the amount of alcohol and other reducing material should be so large during the 3 days of experiment No. 21 is rather surprising. During the 4 days of the preliminary period and the 6 days of experiments Nos. 18–20, 725 grams of absolute alcohol had been taken. It may be that there was a certain lag in the elimination of alcohol not oxidized by the body. That there could be any large amount of alcohol remaining in the body seems altogether improbable, both from physiological considerations and from the results of experiments which have been made concerning the amount of alcohol which may be found in the tissues of the body. If there were a lag in the elimination, we do not know how long it would continue. In later experiments, Nos. 22, 27, and 33, no such lag was observed. The figures for reducing material in the alcohol on the 3 days of experiment No. 21 are not as trustworthy as those of the previous days, owing to certain analytical irregularities. The figures in column 5 of Table XLII show the total excretion of alcohol on the arbitrary assumption that one-half the average amount of reducing material found in experiment No. 21 was actually alcohol. While it is believed that these amounts represent more than the actual elimination of alcohol, they have been used in the computations of the income and outgo of carbon and energy in the following tables:

TABLE XLII.—*Alcohol ingested and excreted—Metabolism experiments Nos. 18–20.*[a]

Date.	Alcohol ingested.	Alcohol excreted, including other reducing material calculated as alcohol.				Total excretions, corrected for possible lag.	Alcohol metabolized in body.	
		In urine (distillate).	In freezer water (distillate).	In air current.	Total.			
1899.								
Experiment No. 18.	*Grams.*	*Grams.*	*Grams.*	*Grams.*	*Grams.*	*Grams.*	*Grams.*	*Per cent.*
Feb. 6–7	72.5	0.09	0.04	2.03	2.16	3.20	69.3	95.6
7–8	72.5	.18	.03	1.56	1.77	2.81	69.7	96.1
Experiment No. 19.								
Feb. 8–9	72.5	.10	.04	1.53	1.67	2.71	69.8	96.3
9–10	72.5	.14	.04	1.22	1.40	2.44	70.1	96.7
Experiment No. 20.								
Feb. 10–11	72.5	.13	.05	1.23	1.41	2.45	70.1	96.7
11–12	72.5	.15	.05	2.05	2.25	3.29	69.2	95.5
Total	435.0	.79	.25	9.62	10.66	16.90	418.2	....
Average per day	72.5	.13	.04	1.60	1.78	2.82	69.7	96.1
Experiment No. 21.								
Feb. 12–13	....	.11	.05	1.68	1.84	....	....	....
13–14	....	.13	.07	1.80	2.00	....	....	....
14–15	....	.19	.07	2.14	2.40	....	....	....

[a] No. 21 included for comparison.

Balance of income and outgo of matter and energy: The income and outgo of nitrogen, carbon, hydrogen, and energy in these experiments are shown in Tables XLIII to XLVI.

TABLE XLIII.—*Income and outgo of nitrogen and carbon—Metabolism experiments Nos. 18–20.*[a]

Date and period.	Nitrogen.				Carbon.					
	(*a*) In food.	(*b*) In feces.	(*c*) In urine.	(*d*) Gain (+) or loss (−) $a-(b+c)$.	(*e*) In food.	(*f*) In feces.	(*g*) In urine.	(*h*) In respiratory products.	(*i*) In alcohol eliminated.	(*k*) Gain (+) or loss (−), $e-(f+g+h+i)$.
1899.										
Experiment No. 18.	*Grams.*	*Grams.*	*Grams.*	*Grams.*	*Grams.*	*Grams.*	*Grams.*	*Grams.*	*Grams.*	*Grams.*
Feb. 6–7, 7 a. m. to 7 a. m.	15.5	1.0	17.4	−2.9	253.0	9.0	11.0	224.4	1.7	+ 6.9
7–8, 7 a. m. to 7 a. m.	15.5	1.1	15.4	−1.0	253.0	9.0	9.8	214.3	1.4	+18.5
Total for 2 days	31.0	2.1	32.8	−3.9	506.0	18.0	20.8	438.7	3.1	+25.4
Average per day	15.5	1.1	16.4	−2.0	253.0	9.0	10.4	219.3	1.6	+12.7
Experiment No. 19.										
Feb. 8–9, 7 a. m. to 7 a. m.	15.5	1.0	14.7	− .2	253.0	9.0	9.3	206.2	1.4	+27.1
9–10, 7 a. m to 7 a. m	15.5	1.1	14.2	+ .2	253.0	9.0	9.0	207.1	1.3	+26.6
Total for 2 days	31.0	2.1	28.9	....	506.0	18.0	18.3	413.3	2.7	+53.7
Average per day	15.5	1.0	14.5	....	253.0	9.0	9.2	206.6	1.3	+26.9
Experiment No. 20.										
Feb. 10–11, 7 a. m. to 7 a. m.	15.5	1.0	13.8	+ .7	253.0	9.0	8.8	214.1	1.3	+19.8
11–12, 7 a. m. to 7 a. m.	15.5	1.1	14.4	....	253.0	9.0	9.2	218.3	1.7	+14.8
Total for 2 days	31.0	2.1	28.2	+ .7	506.0	18.0	18.0	432.4	3.0	+34.6
Average per day	15.5	1.0	14.1	+ .4	253.0	9.0	9.0	216.2	1.5	+17.3
Experiments Nos. 18–20.										
Average per day	15.5	1.0	15.0	− .5	253.0	9.0	9.5	214.1	1.5	+18.9
Experiment No. 21.										
Feb. 12–13, 7 a. m. to 7 a. m.	15.5	1.0	14.5	....	215.2	9.0	10.2	215.2	......	−19.2
13–14, 7 a. m. to 7 a. m.	15.5	1.1	16.2	−1.8	215.2	9.0	11.3	214.6	......	−19.7
14–15, 7 a. m. to 7 a. m.	15.5	1.0	15.4	− .9	215.2	9.0	10.9	222.5	......	−27.2
Total for 3 days	46.5	3.1	46.1	−2.7	645.6	27.0	32.4	652.3	......	−66.1
Average per day	15.5	1.0	15.4	− .9	215.2	9.0	10.8	217.4	......	−22.0

[a] No. 21 included for comparison.

TABLE XLIV.—*Income and outgo of water and hydrogen—Metabolism experiments Nos. 18–21.*[a]

Date and period.	Water.					
	(*a*) In food.	(*b*) In drink.[b]	(*c*) In feces.	(*d*) In urine.	(*e*) In respiratory products.	(*f*) Apparent loss $a+b-(c+d+e)$.
1899.						
Experiment No. 18.	*Grams.*	*Grams.*	*Grams.*	*Grams.*	*Grams.*	*Grams.*
Feb. 6–7, 7 a. m. to 7 a. m	889.9	1,398.2	46.4	1,269.3	896.4	+ 76.0
7–8. 7 a. m. to 7 a. m	889.9	1,384.8	46.4	1,945.4	871.3	− 588.4
Total for 2 days	1,779.8	2,783.0	92.8	3,214.7	1,767.7	− 512.4
Average per day	889.9	1,391.5	46.4	1,607.3	883.9	− 256.2
Experiment No. 19.						
Feb. 8–9, 7 a. m. to 7 a. m	889.9	1,384.3	46.4	1,437.6	842.1	− 51.9
9–10, 7 a. m. to 7 a. m	889.9	1,383.8	46.4	1,683.3	805.3	− 261.3
Total for 2 days	1,779.8	2,768.1	92.8	3,120.9	1,647.4	− 313.2
Average per day	889.9	1,384.1	46.4	1,560.5	823.7	− 156.6

[a] No. 21 included for comparison.

[b] During the 9 days of these experiments 28.5 grams water was evaporated from the hygrometer, or an average of 3.2 grams per day, which is here added to the drink.

TABLE XLIV.—*Income and outgo of water and hydrogen—Metabolism experiments Nos. 18–21*[a].—Continued.

Date and period.	Water.					
	(a) In food.	(b) In drink.	(c) In feces.	(d) In urine.	(e) In respiratory products,	(f) Apparent loss $a+b-(c+d+e)$.
1899.						
Experiment No. 20.	Grams.	Grams.	Grams.	Grams.	Grams.	Grams.
Feb. 10–11, 7 a. m. to 7 a. m	889.9	1,384.1	46.4	1,646.4	836.3	− 255.1
11–12, 7 a. m. to 7 a. m	889.9	1,385.2	46.4	1,887.9	847.6	− 506.8
Total for 2 days	1,779.8	2,769.3	92.8	3,534.3	1,683.9	− 761.9
Average per day	889.9	1,384.7	46.4	1,767.2	842.0	− 381.0
Average per day (experiments 18–20)	889.9	1,386.7	46.4	1,645.0	849.8	− 264.6
Experiment No. 21.						
Feb. 12–13, 7 a. m. to 7 a. m	889.9	1,385.4	46.4	1,628.3	821.3	− 220.7
13–14, 7 a. m. to 7 a. m	889.9	1,383.8	46.4	1,689.5	858.4	− 320.6
14–15, 7 a. m. to 7 a. m	889.9	1,384.9	46.4	1,909.3	897.6	− 578.5
Total for 3 days	2,669.7	4,154.1	139.2	5,227.1	2,577.3	−1,119.8
Average per day	889.9	1,384.7	46.4	1,742.4	859.1	− 373.3

Date and period.	Hydrogen.						
	(g) In food.	(h) In feces.	(i) In urine.	(k) In alcohol eliminated.	(l) Apparent gain $g-(h+i+k)$.	(m) Loss from water $f\div 9$.	(n) Total gain (+) or loss (−) $l+m$.
1899.							
Experiment No. 18.	Grams.	Grams.	Grams.	Grams.	Grams.	Grams.	Grams.
Feb. 6–7, 7 a. m. to 7 a. m	41.2	1.2	3.6	0.4	+36.0	+ 8.5	+44.5
7–8, 7 a. m. to 7 a. m	41.3	1.3	3.1	.4	+36.5	− 65.4	−28.9
Total for 2 days	82.5	2.5	6.7	.8	+72.5	− 56.9	+15.6
Average per day	41.3	1.3	3.3	.4	+36.3	− 28.5	+ 7.8
Experiment No. 19.							
Feb. 8–9, 7 a. m. to 7 a. m	41.2	1.2	3.0	.4	+36.6	− 5.8	+30.8
9–10, 7 a.m. to 7 a. m	41.3	1.3	2.9	.3	+36.8	− 29.0	+ 7.8
Total for 2 days	82.5	2.5	5.9	.7	+73.4	− 34.8	+38.6
Average per day	41.3	1.3	3.0	.3	+36.7	− 17.4	+19.3
Experiment No. 20.							
Feb. 10–11, 7 a. m. to 7 a. m	41.2	1.2	2.8	.3	+36.9	− 28.4	+ 8.5
11–12, 7 a. m. to 7 a. m	41.3	1.3	2.9	.4	+36.7	− 56.3	−19.6
Total for 2 days	82.5	2.5	5.7	.7	+73.6	− 84.7	−11.1
Average per day	41.3	1.2	2.9	.4	+36.8	− 42.4	− 5.6
Average per day (experiments 18–20)	41.3	1.3	3.0	.4	+36.6	− 29.4	+ 7.2
Experiment No. 21.							
Feb. 12–13, 7 a. m. to 7 a. m	31.8	1.2	2.9	....	+27.7	− 24.5	+ 3.2
13–14, 7 a. m. to 7 a. m	31.8	1.3	3.2	....	+27.3	− 35.6	− 8.3
14–15, 7 a. m. to 7 a. m	31.8	1.2	3.1	....	+27.5	− 64.3	−36.8
Total for 3 days	95.4	3.7	9.2	....	+82.5	−124.4	−41.9
Average per day	31.8	1.2	3.1	....	+27.5	− 41.5	−14.0

[a] No. 21 included for comparison.

[b] During the 9 days of these experiments 28.5 grams water was evaporated from the hygrometer, or an average of 3.2 grams per day, which is here added to the drink.

TABLE XLV.—*Gain or loss of protein (N×6.25), fat, and water—Metabolism experiments Nos. 18–20.*[a]

Date and period.	(a) Nitrogen gained (+) or lost (−).	(b) Protein gained (+) or lost (−) a×6.25.	(c) Total carbon gained (+) or lost (−).	(d) Carbon in protein gained (+) or lost (−) b×0.53.	(e) Carbon in fat, etc., gained (+) or lost (−) c−d.	(f) Fat gained (+) or lost (−) e÷0.765.
1899.						
Experiment No. 18.	*Grams.*	*Grams.*	*Grams.*	*Grams.*	*Grams.*	*Grams.*
Feb. 6–7, 7 a. m. to 7 a. m	−2.9	−18.1	+ 6.9	− 9.6	+16.5	+21.6
7–8, 7 a. m. to 7 a. m	−1.0	− 6.3	+18.5	− 3.3	+21.8	+28.5
Total for 2 days	−3.9	−24.4	+25.4	−12.9	+38.3	+50.1
Average per day	−2.0	−12.2	+12.7	− 6.5	+19.2	+25.1
Experiment No. 19.						
Feb. 8–9, 7 a. m. to 7 a. m	− .2	− 1.3	+27.1	− .7	+27.8	+36.3
9–10, 7 a. m. to 7 a. m	+ .2	+ 1.3	+26.6	+ .7	+25.9	+33.9
Total for 2 days	0	0	+53.7	0	+53.7	+70.2
Average per day	0	0	+26.9	0	+26.9	+35.1
Experiment No. 20.						
Feb. 10–11, 7 a. m. to 7 a. m	+ .7	+ 4.4	+19.8	+ 2.3	+17.5	+22.9
11–12, 7 a. m. to 7 a. m	0	0	+14.8	0	+14.8	+19.3
Total for 2 days	+ .7	+ 4.4	+34.6	+ 2.3	+32.3	+42.2
Average per day	+ .4	+ 2.2	+17.3	+ 1.2	+16.2	+21.1
Average per day (experiments 18–20)	− .5	− 3.3	+18.9	− 1.8	+20.7	+27.1
Experiment No. 21.						
Feb. 12–13, 7 a. m. to 7 a. m	0	0	−19.2	0	−19.2	−25.1
13–14, 7 a. m. to 7 a. m	−1.8	−11.3	−19.7	− 6.0	−13.7	−17.9
14–15, 7 a. m. to 7 a. m	− .9	− 5.6	−27.2	− 3.0	−24.2	−31.6
Total for 3 days	−2.7	−16.9	−66.1	− 9.0	−57.1	−74.6
Average per day	− .9	− 5.6	−22.0	− 3.0	−19.0	−24.9

Date and period.	(g) Total hydrogen gained (+) or lost (−).	(h) Hydrogen in protein gained (+) or lost (−) b×0.07.	(i) Hydrogen in fat gained (+) or lost (−) f×0.12.	(k) Hydrogen in water, etc., gained (+) or lost (−) g−(h+i).	(l) Water gained (+) or lost (−) k×9.
1899.					
Experiment No. 18.	*Grams.*	*Grams.*	*Grams.*	*Grams.*	*Grams.*
Feb. 6–7, 7 a. m. to 7 a. m	+44.5	−1.3	+2.6	+43.2	+389
7–8, 7 a. m. to 7 a. m	−28.9	− .4	+3.4	−31.9	−287
Total for 2 days	+15.6	−1.7	+6.0	+11.3	+102
Average per day	+ 7.8	− .9	+3.0	+ 5.7	+ 51
Experiment No. 19.					
Feb. 8–9, 7 a. m. to 7 a. m	+30.8	− .1	+4.3	+26.6	+240
9–10, 7 a. m. to 7 a. m	+ 7.8	+ .1	+4.1	+ 3.6	+ 32
Total for 2 days	+38.6	0	+8.4	+30.2	+272
Average per day	+19.3	0	+4.2	+15.1	+136
Experiment No. 20.					
Feb. 10–11, 7 a. m. to 7 a. m	+ 8.5	+ .3	+2.8	+ 5.4	+ 48
11–12, 7 a. m. to 7 a. m	−19.6	0	+2.3	−21.9	−197
Total for 2 days	−11.1	+ .3	+5.1	−16.5	−149
Average per day	− 5.6	+ .1	+2.6	− 8.3	− 75
Average per day (experiments 18–20)	+ 7.2	− .2	+3.2	+ 4.2	+ 38
Experiment No. 21.					
Feb. 12–13, 7 a. m. to 7 a. m	+ 3.2	0	−3.0	+ 6.2	+ 56
13–14, 7 a. m. to 7 a. m	− 8.3	− .8	−2.2	− 5.3	− 48
14–15, 7 a. m. to 7 a. m	−36.8	− .4	−3.8	−32.6	−293
Total for 3 days	−41.9	−1.2	−9.0	−31.7	−285
Average per day	−14.0	− .4	−3.0	−10.6	− 95

[a] No. 21 included for comparison.

TABLE XLVI.—*Income and outgo of energy—Metabolism experiments Nos. 18–20.*[a]

Date and period.	(a) Heat of combustion of food eaten.	(b) Heat of combustion of feces.	(c) Heat of combustion of urine.	(d) Heat of combustion of alcohol eliminated.	(e) Estimated heat of combustion of protein gained (+) or lost (−).	(f) Estimated heat of combustion of fat gained (+) or lost (−).	(g) Estimated energy of material oxidized in the body, $a-(b+c+d+e+f)$.	(h) Heat determined.	(i) Heat determined greater (+) or less (−) than estimated $h-g$.	(k) Heat determined greater (+) or less (−) than estimated $i \div g$.
1899.										
Experiment No. 18.	*Calories.*	*Calories.*	*Calories.*	*Calories.*	*Calories.*	*Calories.*	*Calories.*	*Calories.*	*Calories.*	*Per cent.*
Feb. 6–7, 7 a. m. to 7 a. m.	2,776	100	130	23	−104	+203	2,424	2,578	+154	+6.4
7–8, 7 a. m. to 7 a. m.	2,776	100	115	20	− 36	+268	2,309	2,397	+ 88	+3.8
Total for 2 days	5,552	200	245	43	−140	+471	4,733	4,975	+242	......
Average per day	2,776	100	123	21	− 70	+235	2,367	2,488	+121	+5.1
Experiment No. 19.										
Feb. 8–9, 7 a. m. to 7 a. m.	2,776	100	110	19	− 7	+341	2,213	2,281	+ 68	+3.1
9–10, 7 a. m. to 7 a. m.	2,776	100	106	17	+ 7	+319	2,227	2,277	+ 50	+2.2
Total for 2 days	5,552	200	216	36	0	+660	4,440	4,558	+118	......
Average per day	2,776	100	108	18	0	+330	2,220	2,279	+ 59	+2.7
Experiment No. 20.										
Feb. 10–11, 7 a. m. to 7 a. m.	2,776	100	104	18	+ 25	+215	2,314	2,298	− 16	− .7
11–12, 7 a. m. to 7 a. m.	2,776	100	108	23	0	+181	2,364	2,308	− 56	−2.4
Total for 2 days	5,552	200	212	41	+ 25	+396	4,678	4,606	− 72	......
Average per day	2,776	100	106	21	+ 12	+198	2,339	2,303	− 36	−1.5
Average per day (experiments 18–20)	2,776	100	112	20	− 19	+255	2,308	2,356	+ 48	+2.1
Experiment No. 21.										
Feb. 12–13, 7 a. m. to 7 a. m.	2,264	100	119	......	0	−236	2,281	2,226	− 55	−2.4
13–14, 7 a. m. to 7 a. m.	2,264	100	132	......	− 65	−168	2,265	2,263	− 2	− .1
14–15, 7 a. m. to 7 a. m.	2,264	100	127	......	− 32	−297	2,366	2,348	− 18	− .7
Total for 3 days	6,792	300	378	......	− 97	−701	6,912	6,837	− 75	......
Average per day	2,264	100	126	......	− 32	−234	2,304	2,279	− 25	−1.1

[a] No. 21 included for comparison.

EXPERIMENTS NOS. 22–24—REST. NO. 22 WITH ALCOHOL DIET.

Subject.—E. O., who served as the subject of experiments Nos. 12, 15–17, and 18–20, described above. His weight was about 72.5 kilograms (160 pounds).

Occupation during experiment.—Reading, writing, etc., with as little mental and muscular activity as possible.

Duration.—The preliminary period of 4 days began with breakfast, March 9, 1899, and the subject entered the respiration chamber on the evening of March 12; experiment No. 22 beginning at 7 o'clock on the morning of March 13 and continuing 3 days. This experiment was the first of a series of three (Nos. 22–24), each continuing 3 days; the subject, therefore, remained in the respiration chamber 10 nights and 9 days, the series of experiments ending on the morning of March 22.

Diet.—One especial object of the experiments of this series was to study the relative replacing power of alcohol and sugar in the diet. The latter consisted of what may be called a basal ration of ordinary food to which was added a supplementary ration of either sugar or alcohol.

The basal ration furnished 123 grams of protein and 2,535 calories of energy per day. To this ration was added, in experiment No. 22, 79.2 grams of 90.9 per cent commercial alcohol. This contained 72 grams of absolute alcohol and furnished 509 calories of energy. In experiment No. 23 the subject had 30 grams of horse-radish, furnishing 11 calories of energy per day, and in experiment No. 24, 30 grams of horse-radish, furnishing 11 calories of energy, and 130 grams of cane sugar, furnishing 515 calories of energy. Leaving the small quantities of horse-radish out of account, the diet of experiment 22 supplied the basal ration plus alcohol, No. 23 the basal ration alone, and No. 24 the basal ration plus an amount of sugar isodynamic with the alcohol of No. 22. In experiment No. 22 the alcohol was taken in the usual 6 doses, 3 with and 3 between meals and upon retiring. It was prepared by adding 79.2 grams of 90.9 per cent alcohol to 780.8 grams of coffee infusion sweetened with 40 grams of sugar. This mixture thus contained 72 grams of absolute alcohol, 40 grams of sugar, and 788 grams of water. The kinds and quantities of food served at each meal and the quantities of drink at different periods were as follows:

Diet in metabolism experiments Nos. 22–24.

FOOD—BASAL RATION.

	Breakfast.	Dinner.	Supper.	Total.
	Grams.	*Grams.*	*Grams.*	*Grams.*
Beef	75	75	....	150
Butter	15	20	20	55
Milk, skimmed	350	390	390	1,130
Bread	55	100	155	310
Parched cereal	45	....	....	45
Sugar [a]	40	....	....	40

[a] Used with the coffee infusion and alcohol in experiment No. 22.

FOOD—SUPPLEMENTAL RATION.

Last day of preliminary period and during metabolism experiment No. 22:
- Coffee infusion .... grams.. 780.8
- Sugar .... do.... 40.0
- Alcohol (90.9 per cent) .... do.... 79.2

Metabolism experiment No. 23, horse-radish .... do.... 30.0

Metabolism experiment No. 24:
- Horse-radish .... do.... 30.0
- Sugar .... do.... 130.0

DRINK.

	Experiment No. 22.		Experiments Nos. 23 and 24.	
	Coffee infusion, sugar, and alcohol.	Water.	Coffee infusion.	Water.
	Grams.	*Grams.*	*Grams.*	*Grams.*
Breakfast	175	....	263	....
10.30 a. m.	125	200	....	200
Dinner	175	....	263	....
2.30 p. m.	125	200	....	200
Supper	175	....	262	....
11.00 p. m.	125	200	....	200
	[a] 900	[b] 600	[b] 788	[b] 600

[a] Contains 72 grams absolute alcohol and 40 grams sugar.

[b] The subject did not always drink the full schedule allowance of coffee and of water. The actual amount of water consumed each day is shown in the second column of Table LVIII.

Daily routine.—The general routine of the experiment is indicated by the following schedule:

Daily program—Metabolism experiments Nos. 22–24.

7.00 a. m	Rise, pass urine, weigh self, weigh absorbers.	3.30 p. m	Drink 200 grams water.
7.45 a. m	Breakfast.	6.30 p. m	Supper.
10.30 a. m	Drink 200 grams water.	7.00 p. m	Pass urine.
1.00 p. m	Pass urine.	11.00 p. m	Drink 200 grams water, take cap off food aperture, retire.
1.30 p. m	Dinner.		

Table XLVII summarizes the more important statistics in the diary kept by the subject during the series of experiments.

TABLE XLVII.—*Summary of diary—Metabolism experiments Nos. 22–24.*

Date and time.	Weight without clothes.	Pulse rate per minute.	Temperature.	Hygrometer. Dry bulb.	Hygrometer. Wet bulb.
1899.					
Experiment No. 22.					
	Kilograms.		° *F.*	° *C.*	° *C.*
Mar. 13, 7.00 a. m	72.42	60	97.6	20.6	15.8
13, 3.30 p. m		72	97.8	20.2	16.2
13, 11.30 p. m		61	97.2	20.4	16.2
14, 7.00 a. m	73.07	59	97.0	20.4	15.1
14, 3.25 p. m		70	98.0	20.0	15.2
14, 11.00 p. m		70	98.4	20.6	15.8
15, 7.00 a. m	72.86	60	97.2	20.0	14.8
15, 4.15 p. m		68	97.8	20.0	15.2
15, 11.00 p. m		69	98.6	20.4	16.2
Experiment No. 23.					
16, 7.00 a. m	72.89	56	97.0	20.2	15.3
16, 3.30 p. m		76	98.9	20.0	15.4
16, 10.45 p. m		65	98.4	20.4	16.0
17, 7.00 a. m	72.67	58	97.0	20.4	15.1
17, 3.30 p. m		70	98.0	20.0	15.2
17, 10.50 p. m		66	98.0	20.2	15.4
18, 7.00 a. m	72.70	56	96.8	20.3	14.6
18, 3.40 p. m		66	97.6	20.2	15.0
18, 10.50 p. m		66	98.3	20.1	15.2
Experiment No. 24.					
19, 7.00 a. m	72.68	60	96.9	20.2	14.6
19, 3.30 p. m		64	98.5	19.8	14.6
19, 10.50 p. m		69	98.8	20.2	15.0
20, 7.00 a. m	72.70	58	97.0	20.0	14.8
20, 4.00 p. m		73	99.0	20.2	15.4
20, 10.50 p. m		71	99.0	20.4	15.6
21, 7.00 a. m	72.97	56	96.6	20.2	15.0
21, 3.50 p. m		69	99.2	20.2	15.2
21, 10.00 p. m		70	99.4	20.6	16.0
22, 7.00 a. m	72.90	60	97.8	20.8	16.8

Detailed statistics of income and outgo.—The quantities of nutrients in the basal ration and the quantities in the supplemental ration in the different experiments of this series are shown in Table XLVIII. No attempt was made in this experiment to obtain a separation of the feces between experiments 22 and 23, since it was believed the amount of such excretion during the alcohol experiment would not differ materially from the amount in the following experiment in which alcohol was not used but in which the diet was otherwise the same, with the exception of the small amount of horse-radish. It is our experience that too frequent separation of the feces renders the line of demarcation less accurate. The separation of the feces was, however, made between experiments 23 and 24. The data of amount and composition of the feces of the two experiments are given in Table XLIX.

TABLE XLVIII.—*Weight, composition, and heat of combustion of foods—Metabolism experiments Nos. 22–24.*

Laboratory No.	Food material.	Weight per day.	Water.	Protein.	Fat.	Carbohydrates.	Nitrogen.	Carbon.	Hydrogen.	Heat of combustion.
	Basal ration.	*Grams.*	*Grams.*	*Grams.*	*Grams.*	*Grams.*	*Grams.*	*Grams.*	*Grams.*	*Calories.*
3027	Beef	150	84.9	52.3	9.2	....	8.38	35.35	5.05	395
3029	Butter	55	5.2	.6	47.7	....	.09	38.03	5.79	441
3031	Skimmed milk	1,130	1,025.0	40.7	1.1	54.2	6.55	46.44	6.67	462
3032	Bread	310	125.2	24.5	10.5	145.7	3.94	86.95	12.34	896
3004	Parched cereal	45	2.7	5.1	.3	36.2	.82	18.63	2.78	183
	Sugar	40	....	....	....	40.0	....	16.84	2.59	158
		....	1,243.0	123.2	68.8	276.1	19.78	242.24	35.22	2,535
	Supplemental ration.									
	EXPERIMENT NO. 22.									
	Alcohol	72	....	....	....	....	....	37.56	9.39	509
	Total ration per day	....	**1,243.0**	**123.2**	**68.8**	**276.1**	**19.78**	**279.80**	**44.61**	**3,044**
	EXPERIMENT NO. 23.									
3069	Horse-radish	30	26.8	.4	....	2.5	.06	2.70	.18	11
	Total ration per day	....	**1,269.8**	**123.6**	**68.8**	**278.6**	**19.84**	**244.94**	**35.40**	**2,546**
	EXPERIMENT NO. 24.									
3069	Horse-radish	30	26.8	.4	....	2.5	.06	2.70	.18	11
	Rock candy	130	....	....	....	130.0	....	54.72	8.42	515
	Total ration per day	....	**1,269.8**	**123.6**	**68.8**	**408.6**	**19.84**	**299.66**	**43.82**	**3.061**

TABLE XLIX.—*Weight, composition, and heat of combustion of feces—Metabolism experiments Nos. 22–24.*

Laboratory No.		Weight.	Water.	Protein.	Fat.	Carbohydrates.	Nitrogen.	Carbon.	Hydrogen.	Heat of combustion.
		Grams.	*Grams.*	*Grams.*	*Grams.*	*Grams.*	*Grams.*	*Grams.*	*Grams.*	*Calories.*
3035	Total, experiments 22 to 23	425.7	295.0	42.1	22.1	36.2	6.77	61.47	8.81	685
	Average per day	70.9	49.2	7.0	3.7	6.0	1.13	10.25	1.47	114
3036	Total, experiment 24	270.0	204.4	24.5	13.2	14.6	3.91	31.43	4.46	347
	Average per day	90.0	68.1	8.2	4.4	4.9	1.30	10.48	1.49	116

The following table gives the data for the amount and composition of the urine. In previous experiments the urine was collected in 6-hour intervals throughout the day. Inasmuch, however, as the subject at times found it difficult to get to sleep again after emptying the bladder at 1 o'clock in the morning, the urine was collected at 11 p. m., immediately before retiring, instead of 1 a. m., as in the previous experiment. The day is thus subdivided into two periods of 6 hours, one of 4, and one of 8 hours.

During the first 3 days of the preliminary digestion period, the subject eliminated 17.3, 11.8, and 14.6 grams, respectively, of nitrogen in the urine. During these days alcohol did not form a part of the diet. On the third day of the preliminary period, which was the first day upon which alcohol was added to the diet, the elimination of nitrogen in the urine amounted to 13.7 grams. It will be noticed that after the subject entered the apparatus the amount of nitrogen in the urine was larger in amount, but remained quite uniform throughout the whole series of experiments. As has previously been remarked, it is not infrequently the case that an increased elimination of nitrogen takes place when the subject enters the respiration chamber. This may account for the increase in the present case. Another explanation of the increase would be to assume that it was caused by the presence of alcohol in the diet. It is noticeable, however, that it did not take place until the subject entered the calorimeter, a day after alcohol was added to the diet, and that it continued throughout the 9 days of the sojourn in the respiration chamber, during but 3 of which alcohol was a part of the diet. The urine was not collected after the close of the experiments.

TABLE L.—*Amount, specific gravity, and nitrogen of urine, by 6-hour periods—Metabolism experiments Nos. 22–24.*

Date.	Period.	Amount.	Specific gravity.	Nitrogen.	
	Experiment No. 22.				
1899.		*Grams.*		*Per cent.*	*Grams.*
Mar. 13–14	7 a. m. to 1 p. m.	356.6	1.022	1.27	4.53
	1 p. m. to 7 p. m.	377.6	1.024	1.38	5.21
	7 p. m. to 11 p. m.	268.5	1.021	1.51	4.05
	11 p. m. to 7 a. m.	356.7	1.018	1.36	4.85
	Total				18.64
	Total by composite	1,359.4	1.019	1.40	19.04
14–15	7 a. m. to 1 p. m.	671.6	1.009	.62	4.16
	1 p. m. to 7 p. m.	776.8	1.007	.52	4.04
	7 p. m. to 11 p. m.	617.5	1.007	.99	6.11
	11 p. m. to 7 a. m.	310.8	1 018	1.45	4.51
	Total				18.82
	Total by composite	2,376.7	1.011	.80	19.01
15–16	7 a. m. to 1 p. m.	514.9	1.009	.68	3.50
	1 p. m. to 7 p. m.	629.9	1.007	.48	3.02
	7 p. m. to 11 p. m.	493.2	1.018	.96	4.73
	11 p. m. to 7 a. m.	633.5	1.012	1.04	6.59
	Total				17.84
	Total by composite	2,271.5	1.012	.80	18.17
	Experiment No. 23.				
16–17	Total, 7 a. m. to 7 a. m.	2,299.1			18.80
17–18	Total, 7 a. m. to 7 a. m.	2,280.0	1.012		19.61
18–19	Total, 7 a. m. to 7 a. m.	1,996.2	1.013		18.47
	Experiment No. 24.				
19–20	Total, 7 a. m. to 7 a. m.	2,225.5	1.014		19.45
20–21	Total, 7 a. m. to 7 a. m.	1,870.9	1.013		18.07
21–22	Total, 7 a. m. to 7 a. m.	1,861.5	1.014		17.26

TABLE LI.—*Daily elimination of carbon, hydrogen, water, and energy in urine—Metabolism experiments Nos. 22–24.*

Date.	Amount.	Carbon.		Hydrogen.		Water.		Heat of combustion.	
								Per gram.	Total.
1899.									
Experiment No. 22.	*Grams.*	*Per ct.*	*Grams.*	*Per ct.*	*Grams.*	*Per ct.*	*Grams.*	*Calories.*	*Calories.*
Mar. 13–14	1,359.4	......	12.01	......	3.52	......	1,295.2	....	139
14–15	2,376.7	......	12.12	......	3.55	......	2,311.8	....	140
15–16	2,271.5	......	11.49	......	3.37	......	2,210.0	....	133
Experiment No. 23.									
Mar. 16–17	2,299.1	......	12.11	......	3.55	......	2,234.3	....	140
17–18	2,280.0	......	12.62	......	3.70	......	2,212.4	....	146
18–19	1,996.2	......	11.90	......	3.49	......	1,932.5	....	137
Experiment No. 24.									
Mar. 19–20	2,225.5	......	12.53	......	3.67	......	2,158.5	....	145
20–21	1,870.9	......	11.64	......	3.41	......	1,808.6	....	134
21–22	1,861.5	......	11.11	......	3.26	......	1,802.0	....	128
Total, 9 days	18,540.8	.58	107.53	.17	31.52	96.9	17,965.3	6.067	1,242

The results of the determinations of carbon dioxid and water in the ventilating air current are given in Tables LII–LIV. These statistics are given in detail for the first 3 days of the series and are summarized by days for the following 6 days, in order to serve as a basis of comparison of the results with and without alcohol as a part of the diet.

TABLE LII.—*Comparison of residual amounts of carbon dioxid and water in the chamber at the beginning and end of each period, and the corresponding gain or loss—Metabolism experiment No. 22.*

Date.	End of period.	Carbon dioxid.		Water.[a]		
		Total amount in chamber.	Gain (+) or loss (−) over preceding period.	Total amount of vapor remaining in chamber.	Gain (+) or loss (−) over preceding period.	Total amount gained (+) or lost (−) during the period.
1899.		*Grams.*	*Grams.*	*Grams.*	*Grams.*	*Grams.*
Mar. 13	7 a. m	28.6	....	38.6	....	....
13–14	1 p. m	36.4	+ 7.8	47.4	+8.8	+8.8
	7 p. m	37.7	+ 1.3	47.0	− .4	− .4
	1 a. m	27.1	−10.6	45.7	−1.3	−1.3
	7 a. m	26.2	− .9	42.4	−3.3	−3.3
	Total	....	− 2.4	....	+3.8	+3.8
14–15	1 p. m	39.3	+13.1	41.9	− .5	− .5
	7 p. m	37.6	− 1.7	40.6	−1.3	−1.3
	1 a. m	28.7	− 8.9	42.5	+1.9	+1.9
	7 a. m	24.6	− 4.1	36.0	−6.5	−6.5
	Total	....	− 1.6	....	−6.4	−6.4
15–16	1 p. m	36.8	+12.2	38.6	+2.6	+2.6
	7 p. m	41.9	+ 5.1	41.5	+2.9	+2.9
	1 a. m	30.2	−11.7	42.3	+ .8	+ .8
	7 a. m	24.5	− 5.7	35.2	−7.1	−7.1
	Total	....	− .1	....	− .8	− .8

[a] In these experiments there was no change in weight of absorbers and there was no drip.

TABLE LIII.—*Record of carbon dioxid in ventilating air current—Metabolism experiments Nos. 22–24.*

Date.	Period.	(a) Ventilation. Number of liters of air.	Carbon dioxid. In incoming air. (b) Per liter.	(c) Total $a \times b$.	(d) In outgoing air.	(e) Total excess in outgoing air $d-c$.	(f) Correction for amount remaining in chamber.	(g) Corrected amount exhaled by subject $e+f$.	(h) Total weight of carbon exhaled $g \times \frac{3}{11}$.
	Experiment No. 22.								
1899.		*Liters.*	*Mg.*	*Grams.*	*Grams.*	*Grams.*	*Grams.*	*Grams.*	*Grams.*
Mar. 13–14	7 a. m. to 1 p. m.	26, 085	0. 610	15. 9	241. 5	225. 6	+ 7. 8	233. 4	63. 6
	1 p. m. to 7 p. m.	26, 212	. 587	15. 4	226. 0	210. 6	+ 1. 3	211. 9	57. 8
	7 p. m. to 1 a. m.	27, 942	. 574	16. 0	209. 3	193. 3	−10. 6	182. 7	49. 8
	1 a. m. to 7 a. m.	27, 945	. 591	16. 5	156. 7	140. 2	− . 9	139. 3	38. 0
	Total	108, 184	....	63. 8	833. 5	769. 7	− 2. 4	767. 3	209. 2
14–15	7 a. m. to 1 p. m.	26, 606	. 588	15. 6	228. 6	213. 0	+13. 1	226. 1	61. 7
	1 p. m. to 7 p. m.	27, 595	. 569	15. 7	221. 4	205. 7	− 1. 7	204. 0	55. 6
	7 p. m. to 1 a. m.	27, 873	. 563	15. 7	212. 8	197. 1	− 8. 9	188. 2	51. 3
	1 a. m. to 7 a. m.	27, 604	. 577	15. 9	149. 5	133. 6	− 4. 1	129. 5	35. 3
	Total	109, 678	....	62. 9	812. 3	749. 4	− 1. 6	747. 8	203. 9
15–16	7 a. m. to 1 p. m.	26, 590	. 564	15. 0	219. 5	204. 5	+12. 2	216. 7	59. 1
	1 p. m. to 7 p. m.	26, 841	. 576	15. 5	230. 1	214. 6	+ 5. 1	219. 7	59. 9
	7 p. m. to 1 a. m.	28, 013	. 582	16. 3	229. 2	212. 9	−11. 7	201. 2	54. 9
	1 a. m. to 7 a. m.	29, 057	. 576	16. 7	156. 3	139. 6	− 5. 7	133. 9	36. 5
	Total	110, 501	....	63. 5	835. 1	771. 6	− . 1	771. 5	210. 4
	Experiment No. 23.								
16–17	7 a. m. to 7 a. m.	106, 553	....	68. 6	865. 4	796. 8	+ . 7	797. 5	217. 5
17–18	7 a. m. to 7 a. m.	110, 227	....	63. 3	846. 9	783. 6	− . 2	783. 4	213. 6
18–19	7 a. m. to 7 a. m.	107, 982	....	61. 3	860. 3	799. 0	+ 1. 4	800. 4	218. 2
	Experiment No. 24.								
19–20	7 a. m. to 7 a. m	110, 641	....	67. 2	887. 2	820. 0	− 1. 4	821. 4	224. 0
20–21	7 a. m. to 7 a. m	108, 528	....	61. 9	904. 8	842. 9	− 3. 7	839. 2	228. 8
21–22	7 a. m. to 7 a. m	107, 299	....	62. 5	935. 7	873. 2	+ 6. 3	879. 5	239. 8

TABLE LIV.—*Record of water in ventilating air current—Metabolism experiments Nos. 22–24.*

Date.	Period.	(*a*)	Water in incoming air.		Water in outgoing air.			(*g*)	(*h*)	(*i*)
		Ventilation. Number of liters of air.	(*b*) Per liter.	(*c*) Total *a×b*.	(*d*) Amount condensed in freezers.	(*e*) Amount not condensed in freezers.	(*f*) Total *d+e*.	Total excess water in outgoing air *f−c*.	Correction for water remaining in chamber.	Total water of respiration and perspiration *g+h*.
	Experiment No. 22.									
1899.		*Liters.*	*Mg.*	*Grams.*	*Grams.*	*Grams.*	*Grams.*	*Grams.*	*Grams.*	*Grams.*
Mar. 13–14	7 a. m. to 1 p. m.	26,085	0.946	24.7	207.2	45.7	252.9	228.2	+8.8	237.0
	1 p. m. to 7 p. m.	26,212	.882	23.1	225.3	40.0	265.3	242.2	− .4	241.8
	7 p. m. to 1 a. m.	27,942	.827	23.1	235.6	43.7	279.3	256.2	−1.3	254.9
	1 a. m. to 7 a. m.	27,945	.782	21.9	237.1	39.0	276.1	254.2	−3.3	250.9
	Total	108,184	......	92.8	905.2	168.4	1,073.6	980.8	+3.8	984.6
14–15	7 a. m. to 1 p. m.	26,606	.784	20.8	203.0	40.1	243.1	222.3	−0.5	221.8
	1 p. m. to 7 p. m.	27,595	.766	21.2	197.9	37.4	235.3	214.1	−1.3	212.8
	7 p. m. to 1 a. m.	27,873	.745	20.8	203.9	39.9	243.8	223.0	+1.9	224.9
	1 a. m. to 7 a. m.	27,604	.773	21.3	194.0	36.4	230.4	209.1	−6.5	202.6
	Total	109,678	......	84.1	798.8	153.8	952.6	868.5	−6.4	862.1
15–16	7 a. m. to 1 p. m.	26,590	.803	21.4	179.1	39.3	218.4	197.0	+ 2.6	199.6
	1 p. m. to 7 p. m.	26,841	.789	21.2	192.3	36.0	228.3	207.1	+ 2.9	210.0
	7 p. m. to 1 a. m.	28,013	.789	22.1	218.5	42.2	260.7	238.6	+ .8	239.4
	1 a. m. to 7 a. m.	29,057	.820	23.8	202.1	38.6	240.7	216.9	− 7.1	209.8
	Total	110,501	......	88.5	792.0	156.1	948.1	859.6	− .8	858.8
	Experiment No. 23.									
16–17	7 a. m. to 1 p. m.	24,857	.830	20.6	180.1	35.5	215.6	195.0	+ 5.3	200.3
	1 p. m. to 7 p. m.	26,329	.787	20.7	193.5	35.5	229.0	208.3	+ 2.7	211.0
	7 p. m. to 1 a. m.	27,749	.719	20.0	232.4	42.3	274.7	254.7	+ 2.4	257.1
	1 a. m. to 7 a. m.	27,618	.730	20.2	208.4	35.6	244.0	223.8	− 7.9	215.9
	Total	106,553	......	81.5	814.4	148.9	963.3	881.8	+ 2.5	884.3
17–18	7 a. m. to 7 a. m.	110,227	......	79.3	762.1	151.9	914.0	834.7	− 4.2	830.5
18–19	7 a. m. to 7 a. m.	107,982	......	83.3	740.5	148.8	889.3	806.0	+ 1.0	807.0
	Experiment No. 24.									
19–20	7 a. m. to 7 a. m.	110,641	......	85.5	808.2	152.3	960.5	875.0	+ 4.4	879.4
20–21	7 a. m. to 7 a. m.	108,528	......	77.2	814.9	143.5	958.4	881.2	− 2.2	879.0
21–22	7 a. m. to 7 a. m.	107,299	......	76.5	886.5	142.2	1,028.7	952.2	+10.1	962.3
	Total for 9 days	979,593	......	748.7	7,322.6	1,365.9	8,688.5	7,939.8	+ 8.2	7,948.0

The summary of the calorimetric measurements during this series of experiments is shown in Table LV. The results of experiments Nos. 23 and 24 are summarized by days, and those for experiment No. 22, in which alcohol formed a part of the diet, are summarized by 6-hour periods.

TABLE LV.—*Summary of calorimetric measurements—Metabolism experiments Nos. 22–24.*

Date.	Period.	(*a*) Heat measured in terms of C_{20}.	(*b*) Change of temperature of calorimeter.	(*c*) Capacity correction of calorimeter $b \times 60$.	(*d*) Correction due to temperature of food and dishes.	(*e*) Water vaporized equals total amount exhaled less amount condensed in chamber.	(*f*) Heat used in vaporization of water $e \times 0.592$.	(*g*) Total heat determined $(a+c+d+f)$.
	Experiment No. 22.							
1899.		*Calories.*	*Degrees.*	*Calories.*	*Calories.*	*Grams.*	*Calories.*	*Calories.*
Mar. 13–14	7 a. m. to 1 p. m.	547.4	....	....	− 1.1	237.0	140.3	686.6
	1 p. m. to 7 p. m.	486.1	−0.03	− 1.80	+ 3.2	241.8	143.2	630.7
	7 p. m. to 1 a. m.	413.4	+ .02	+ 1.20	....	254.9	150.9	565.5
	1 a. m. to 7 a. m.	280.6	+ .07	+ 4.20	....	250.9	148.5	433.3
	Total	1,727.5	+ .06	+ 3.60	+ 2.1	984.6	582.9	2,316.1
14–15	7 a. m. to 1 p. m.	504.1	− .06	− 3.60	− 0.6	221.8	131.3	631.2
	1 p. m. to 7 p. m.	488.7	− .03	− 1.80	+ 4.5	212.8	126.0	617.4
	7 p. m. to 1 a. m.	427.7	+ .01	+ .60	....	224.9	133.1	561.4
	1 a. m. to 7 a. m.	267.7	+ .04	+ 2.40	....	202.6	120.0	390.1
	Total	1,688.2	− .04	− 2.40	+ 3.9	862.1	510.4	2,200.1
15–16	7 a. m. to 1 p. m.	475.2	+ .03	+ 1.80	− 1.8	199.6	118.2	593.4
	1 p. m. to 7 p. m.	518.3	− .05	− 3.00	+ 5.4	210.0	124.3	645.0
	7 p. m. to 1 a. m.	454.3	− .01	− .60	....	239.4	141.7	595.4
	1 a. m. to 7 a. m.	310.8	− .15	− 9.00	....	209.8	124.2	426.0
	Total	1,758.6	− .18	−10.80	+ 3.6	858.8	508.4	2,259.8
	Experiment No. 23.							
16–17	7 a. m. to 7 a. m.	1,711.0	+ .14	+ 8.40	−41.4	884.3	523.5	2,201.5
17–18	7 a. m. to 7 a. m.	1,700.3	+ .01	+ .60	−47.3	830.5	491.6	2,145.2
18–19	7 a. m. to 7 a. m.	1,750.4	− .06	− 3.60	−44.1	807.0	477.8	2,180.5
	Experiment No. 24.							
19–20	7 a. m. to 7 a. m.	1,737.8	+ .09	+ 5.40	−48.4	879.4	520.6	2,215.4
20–21	7 a. m. to 7 a. m.	1,752.7	− .07	− 4.20	−46.1	879.0	520.3	2,222.7
21–22	7 a. m. to 7 a. m.	1,851.5	+ .04	+ 2.40	−44.6	962.3	569.7	2,379.0

The determinations of alcohol in urine and freezer water, and of reducing material reckoned as alcohol in the ventilating air current, were made in the usual manner. The results are shown in Table LVI. It will be noticed that there was a considerable amount of reducing material in the air and urine on days in which alcohol did not form a part of the diet, equivalent on an average to 0.37 of a gram of alcohol per day. It is of course possible that this reducing material may have been alcohol that had been retained in the system and was slowly eliminated. This, however, seems improbable, especially in view of the fact that the results are no larger than have been found in later experiments in the ventilating air current when alcohol had not formed a part of the diet for a long period. To be strictly accurate, the total amounts of alcohol excreted on the different days of experiment No. 22 should be reduced by a certain amount representing the average excretion of reducing material not alcohol. Inasmuch, however, as this was a matter still under investigation no such correction was made in this experiment, and the results were computed on the supposition that all the reducing material in the air current was alcohol, although from later investigations it seems quite certain that this is wrong. The error, however, would probably not exceed 0.3 or 0.4 of a gram of alcohol, corresponding to 2 or 3 calories of energy per day.

TABLE LVI.—*Alcohol ingested and excreted—Metabolism experiment No. 22.*

Date.	Alcohol ingested.	Alcohol excreted, including other reducing material calculated as alcohol.				Alcohol metabolized in body.	
		In urine (distillate).	In freezer water (distillate).	In air current.	Total.		
1899.							
Experiment No. 22.	*Grams.*	*Grams.*	*Grams.*	*Grams.*	*Grams.*	*Grams.*	*Per cent.*
Mar. 13–14	72.0	0.14	0.03	1.57	1.74	70.3	97.6
14–15	72.0	.68	.02	1.36	2.06	69.9	97.1
15–16	72.0	.75	.03	2.01	2.79	69.2	96.1
Total	216.0	1.57	.08	4.94	6.59	209.4	....
Average per day	72.0	.52	.03	1.65	2.20	69.8	97.0
Experiment No. 23.							
Mar. 16–17	....	.01	....	.30	.31	....	....
17–18	....	.02	.01	.38	.41	....	....
18–19	....	.04	.01	.37	.42	....	....
Experiment No. 24.							
Mar. 19–20	....	.04	....	.27	.31	....	....
20–21	....	.04	.01	.36	.41	....	....
21–22	....	....	....	.37	.37	....	....

Balance of income and outgo of matter and energy.—The usual summary of the income and outgo of nitrogen, carbon, hydrogen, and energy may be found in Table LVII.

TABLE LVII.—*Income and outgo of nitrogen and carbon—Metabolism experiments Nos. 22–24.*

Date and period.	Nitrogen.				Carbon.					
	(*a*) In food.	(*b*) In feces.	(*c*) In urine.	(*d*) Gain (+) or loss (−) *a*−(*b*+*c*).	(*e*) In food.	(*f*) In feces.	(*g*) In urine.	(*h*) In respiratory products.	(*i*) In alcohol eliminated.	(*k*) Gain (+) or loss (−) *e*−(*f*+*g*+*h*+*i*).
1899.										
Experiment No. 22.	*Grams.*	*Grams.*	*Grams.*	*Grams.*	*Grams.*	*Grams.*	*Grams.*	*Grams.*	*Grams.*	*Grams.*
Mar. 13–14, 7 a. m. to 7 a. m.	19.8	1.1	18.7	....	279.8	10.3	12.0	209.2	0.9	+ 47.4
14–15, 7 a. m. to 7 a. m.	19.8	1.2	18.8	−0.2	279.8	10.2	12.1	203.9	1.1	+ 52.5
15–16, 7 a. m. to 7 a. m.	19.8	1.1	17.8	+ .9	279.8	10.3	11.5	210.4	1.5	+ 46.1
Total for 3 days	59.4	3.4	55.3	+ .7	839.4	30.8	35.6	623.5	3.5	+146.0
Average per day	19.8	1.1	18.5	+ .2	579.8	10.3	11.8	207.8	1.2	+ 48.7
Experiment No. 23.										
Mar. 16–17, 7 a. m. to 7 a. m.	19.8	1.1	18.8	− .1	244.9	10.2	12.1	217.5	....	+ 5.1
17–18, 7 a. m. to 7 a. m.	19.9	1.2	19.6	− .9	245.0	10.3	12.6	213.6	....	+ 8.5
18–19, 7 a. m. to 7 a. m.	19.8	1.1	18.5	+ .2	244.9	10.2	11.9	218.2	....	+ 4.6
Total for 3 days	59.5	3.4	56.9	− .8	734.8	30.7	36.6	649.3	....	+ 18.2
Average per day	19.8	1.1	19.0	− .3	244.9	10.2	12.2	216.4	....	+ 6.1
Experiment No. 24.										
Mar. 19–20, 7 a. m. to 7 a. m.	19.8	1.3	19.4	− .9	299.7	10.5	12.5	224.0	....	+ 52.7
20–21, 7 a. m. to 7 a. m.	19.9	1.3	18.1	+ .5	299.6	10.5	11.7	228.8	....	+ 48.6
21–22, 7 a. m. to 7 a. m.	19.8	1.3	17.3	+1.2	299.7	10.5	11.1	239.8	....	+ 38.3
Total for 3 days	59.5	3.9	54.8	+ .8	899.0	31.5	35.3	692.6	....	+139.6
Average per day	19.8	1.3	18.2	+ .3	299.7	10.5	11.8	230.9	....	+ 46.5

TABLE LVIII.—*Income and outgo of water and hydrogen—Metabolism experiments Nos. 22–24.*

Date and period.	Water. (a) In food.	(b) In drink.	(c) In feces.	(d) In urine.	(e) In respiratory products.	(f) Apparent loss $a+b-(c+d+e)$.
1899.						
Experiment No. 22.	*Grams.*	*Grams.*	*Grams.*	*Grams.*	*Grams.*	*Grams.*
Mar. 13–14, 7 a. m. to 7 a. m	1,243.0	1,387.8	49.2	1,295.2	984.6	[a] + 301.8
14–15, 7 a. m. to 7 a. m	1,243.0	1,388.0	49.2	2,311.8	862.1	− 592.1
15–16, 7 a. m. to 7 a. m	1,243.0	1,387.7	49.2	2,210.0	858.8	− 487.3
Total for 3 days	3,729.0	4,163.5	147.6	5,817.0	2,705.5	− 777.6
Average per day	1,243.0	1,387.8	49.2	1,939.0	901.8	− 259.2
Experiment No. 23.						
Mar. 16–17, 7 a. m. to 7 a. m	1,269.8	1,362.8	49.2	2,234.3	884.3	− 535.2
17–18, 7 a. m. to 7 a. m	1,269.8	1,379.2	49.2	2,212.4	830.5	− 443.1
18–19, 7 a. m. to 7 a. m	1,269.8	1,378.0	49.2	1,932.5	807.0	− 140.9
Total for 3 days	3,809.4	4,120.0	147.6	6,379.2	2,521.8	−1,119.2
Average per day	1,269.8	1,373.3	49.2	2,126.4	840.6	− 373.1
Experiment No. 24.						
Mar. 19–20, 7 a. m. to 7 a. m	1,269.8	1,376.0	68.1	2,158.5	879.4	− 460.2
20–21, 7 a. m. to 7 a. m	1,269.8	1,382.4	68.1	1,808.6	879.0	− 103.5
21–22, 7 a. m. to 7 a. m	1,269.8	1,373.4	68.1	1,802.0	962.3	− 189.2
Total for 3 days	3,809.4	4,131.8	204.3	5,769.1	2,720.7	− 752.9
Average per day	1,269.8	1,377.3	68.1	1,923.0	906.9	− 250.9

Date and period.	Hydrogen. (g) In food.	(h) In feces.	(i) In urine.	(k) In alcohol eliminated.	(l) Apparent gain $g-(h+i+k)$.	(m) Loss from water $(f \div 9)$.	(n) Total gain (+) or loss (−) $l+m$.
1899.							
Experiment No. 22.	*Grams.*	*Grams.*	*Grams.*	*Grams.*	*Grams.*	*Grams.*	*Grams.*
Mar. 13–14, 7 a. m. to 7 a. m	44.6	1.4	3.5	0.2	+ 39.5	+ 33.5	+73.0
14–15, 7 a. m. to 7 a. m	44.6	1.5	3.5	.3	+ 39.3	− 65.8	−26.5
15–16, 7 a. m. to 7 a. m	44.6	1.4	3.4	.4	+ 39.4	− 54.1	−14.7
Total for 3 days	133.8	4.3	10.4	.9	+118.2	− 86.4	+31.8
Average per day	44.6	1.4	3.5	.3	+ 39.4	− 28.8	+10.6
Experiment No. 23.							
Mar. 16–17, 7 a. m. to 7 a. m	35.4	1.5	3.5	....	+ 30.4	− 59.5	−29.1
17–18, 7 a. m. to 7 a. m	35.4	1.4	3.7	....	+ 30.3	− 49.2	−18.9
18–19, 7 a. m. to 7 a. m	35.4	1.5	3.5	....	+ 30.4	− 15.7	+14.7
Total for 3 days	106.2	4.4	10.7	....	+ 91.1	−124.4	−33.3
Average per day	35.4	1.5	3.5	....	+ 30.4	− 41.5	−11.1
Experiment No. 24.							
Mar. 19–20, 7 a. m. to 7 a. m	43.8	1.5	3.7	....	+ 38.6	− 51.1	−12.5
20–21, 7 a. m. to 7 a. m	43.8	1.5	3.4	....	+ 38.9	− 11.5	+27.4
21–22, 7 a. m. to 7 a. m	43.8	1.5	3.3	....	+ 39.0	− 21.0	+18.0
Total for 3 days	131.4	4.5	10.4	....	+116.5	− 83.6	+32.9
Average per day	43.8	1.5	3.5	....	+ 38.8	− 27.9	+10.9

[a] Compare weight of urine eliminated on this day with that on succeeding days.

TABLE LIX.—*Gain or loss of protein ($N \times 6.25$), fat, and water—Metabolism experiments Nos. 22–24.*

Date and period.	(a) Nitrogen gained (+) or lost (−).	(b) Protein gained (+) or lost (−), a×6.25.	(c) Total carbon gained (+) or lost (−).	(d) Carbon in protein gained (+) or lost (−), b×0.53.	(e) Carbon in fat, etc., gained (+) or lost (−), c−d.	(f) Fat gained (+) or lost (−), e÷0.765.
1899.						
Experiment No. 22.	*Grams.*	*Grams.*	*Grams.*	*Grams.*	*Grams.*	*Grams.*
Mar. 13–14, 7 a. m. to 7 a. m.	0.0	0.0	+ 47.4	0.0	+ 47.4	+ 62.0
14–15, 7 a. m. to 7 a. m.	− .2	−1.3	+ 52.5	− .7	+ 53.2	+ 69.5
15–16, 7 a. m. to 7 a. m.	+ .9	+5.6	+ 46.1	+2.9	+ 43.2	+ 56.5
Total for 3 days	+ .7	+4.3	+146.0	+2.2	+143.8	+188.0
Average per day	+ .2	+1.4	+ 48.7	+ .7	+ 48.0	+ 62.7
Experiment No. 23.						
Mar. 16–17, 7 a. m. to 7 a. m.	− .1	− .6	+ 5.1	0.0	+ 5.1	+ 6.7
17–18, 7 a. m. to 7 a. m.	− .9	−5.6	+ 8.5	−3.0	+ 11.5	+ 15.0
18–19, 7 a. m. to 7 a. m.	+ .2	+1.3	+ 4.6	+ .7	+ 3.9	+ 5.1
Total for 3 days	− .8	−4.9	+ 18.2	−2.3	+ 20.5	+ 26.8
Average per day	− .3	−1.6	+ 6.1	− .8	+ 6.9	+ 9.0
Experiment No. 24.						
Mar. 19–20, 7 a. m. to 7 a. m.	− .9	−5.6	+ 52.7	−3.0	+ 55.7	+ 72.8
20–21, 7 a. m. to 7 a. m.	+ .5	+3.1	+ 48.6	+1.6	+ 47.0	+ 61.5
21–22, 7 a. m. to 7 a. m.	+1.2	+7.5	+ 38.3	+4.0	+ 34.3	+ 44.8
Total for 3 days	+ .8	+5.0	+139.6	+2.6	+137.0	+179.1
Average per day	+ .3	+1.7	+ 46.5	+ .9	+ 45.7	+ 59.7

Date and period.	(g) Total hydrogen gained (+) or lost (−).	(h) Hydrogen in protein gained (+) or lost (−), b×0.07.	(i) Hydrogen in fat gained (+) or lost (−), f×0.12.	(k) Hydrogen in water, etc., gained (+) or lost (−), g−(h+i).	(l) Water gained (+) or lost (−), k×9.
1899.					
Experiment No. 22.	*Grams.*	*Gram.*	*Grams.*	*Grams.*	*Grams.*
Mar. 13–14, 7 a. m. to 7 a. m.	+73.0	0.0	+ 7.4	+65.6	[a] +590.4
14–15, 7 a. m. to 7 a. m.	−26.5	− .1	+ 8.3	−34.7	−312.3
15–16, 7 a. m. to 7 a. m.	−14.7	+ .4	+ 6.8	−21.9	−197.1
Total for 3 days	+31.8	+ .3	+22.5	+ 9.0	+ 81.0
Average per day	+10.6	+ .1	+ 7.5	+ 3.0	+ 27.0
Experiment No. 23.					
Mar. 16–17, 7 a. m. to 7 a. m.	−29.1	.0	+ .8	−29.9	−269.1
17–18, 7 a. m. to 7 a. m.	−18.9	− .4	+ 1.8	−20.3	−182.7
18–19, 7 a. m. to 7 a. m.	+14.7	+ .1	+ .6	+14.0	+126.0
Total for 3 days	−33.3	− .3	+ 3.2	−36.2	−325.8
Average per day	−11.1	− .1	+ 1.1	−12.1	−108.6
Experiment No. 24.					
Mar. 19–20, 7 a. m. to 7 a. m.	−12.5	− .4	+ 8.7	−20.8	−187.2
20–21, 7 a. m. to 7 a. m.	+27.4	+ .2	+ 7.4	+19.8	+178.2
21–22, 7 a. m. to 7 a. m.	+18.0	+ .5	+ 5.4	+12.1	+108.9
Total for 3 days	+32.9	+ .3	+21.5	+11.1	+ 99.9
Average per day	+10.9	+ .1	+ 7.1	+ 3.7	+ 33.3

[a] Compare weight of urine eliminated on this day with that on succeeding days.

TABLE LX.—*Income and outgo of energy—Metabolism experiments Nos. 22–24.*

Date and period.	(a) Heat of combustion of food eaten.	(b) Heat of combustion of feces.	(c) Heat of combustion of urine.	(d) Heat of combustion of alcohol eliminated.	(e) Estimated heat of combustion of protein gained (+) or lost (−).	(f) Estimated heat of combustion of fat gained (+) or lost (−).	(g) Estimated energy of material oxidized in the body $a-(b+c+d+e+f)$.	(h) Heat determined.	(i) Heat determined greater (+) or less (−) than estimated $h-g$.	(k) Heat determined greater (+) or less (−) than estimated $i \div g$.
1899.										
Experiment No. 22.	*Calories.*	*Calories.*	*Calories.*	*Calories.*	*Calories.*	*Calories.*	*Calories.*	*Calories.*	*Calories.*	*Per cent.*
Mar. 13–14, 7 a. m. to 7 a. m.	3,044	114	139	12	0	+ 583	2,196	2,316	+120	+5.5
14–15, 7 a. m. to 7 a. m.	3,044	114	140	14	− 8	+ 653	2,131	2,200	+ 69	+3.2
15–16, 7 a. m. to 7 a. m.	3,044	114	133	20	+32	+ 531	2,214	2,260	+ 46	+2.1
Total for 3 days	9,132	342	412	46	+24	+1,767	6,541	6,776	+235	....
Average per day	3,044	114	138	15	+ 8	+ 589	2,180	2,258	+ 78	+3.6
Experiment No. 23.										
Mar. 16–17, 7 a. m. to 7 a. m.	2,546	114	140	....	− 4	+ 63	2,233	2,202	− 31	−1.4
17–18, 7 a. m. to 7 a. m.	2,546	114	146	....	−32	+ 141	2,177	2,145	− 32	−1.5
18–19, 7 a. m. to 7 a. m.	2,546	114	137	....	+ 8	+ 48	2,239	2,181	− 58	−2.6
Total for 3 days	7,638	342	423	....	−28	+ 252	6,649	6,528	−121	....
Average per day	2,546	114	141	....	− 9	+ 84	2,216	2,176	− 40	−1.8
Experiment No. 24.										
Mar. 19–20, 7 a. m. to 7 a. m.	3,061	116	145	....	−32	+ 684	2,148	2,215	+ 67	+3.1
20–21, 7 a. m. to 7 a. m.	3,061	116	134	....	+18	+ 579	2,214	2,223	+ 9	+ .4
21–22, 7 a. m. to 7 a. m.	3,061	116	128	....	+43	+ 421	2,353	2,379	+ 26	+1.1
Total for 3 days	9,183	348	407	....	+29	+1,684	6,715	6,817	+102	....
Average per day	3,061	116	136	....	+10	+ 561	2,238	2,272	+ 34	+1.5

EXPERIMENTS NOS. 26–28—REST. NO. 27 WITH ALCOHOL DIET.

Subject.—J. F. S., a chemist, 29 years of age. His weight with underclothing was about 64 kilograms (141 pounds).

Occupation during experiment.—Reading, writing, and miscellaneous observations within the apparatus, with as little muscular activity as was practicable.

Duration.—This experiment was the second of a series of 3 experiments, each continuing 3 days. The series was preceded by a preliminary period of 4 days, beginning with breakfast February 10, 1900. The subject entered the calorimeter on the evening of February 13. The first experiment of the series, No. 26, began at 7 a. m. February 14; the second, No. 27, at 7 a. m. February 17, and the third, No. 28, at 7 a. m. February 20. The whole period of the metabolism experiments was thus 9 days.

Diet.—A basal ration of ordinary food furnished 99 grams of protein and 1,982 calories of energy per day. To this was added in experiment No. 26, 63.5 grams of butter, furnishing 1 gram of protein and 508 calories of energy; in experiment No. 27, 79.5 grams of 90.6 per cent alcohol, furnishing 509 calories of energy, and in No. 28, 128 grams of cane sugar, furnishing 507 calories of energy per day. The protein and energy was thus practically the same in each of the 3 experiments of this series. In experiment No. 27 the 79.5 grams of commercial alcohol, containing 72 grams absolute alcohol, was added to 792.5 grams of water sweetened with 15 grams of sugar. The alcohol was taken in 6 doses, as indicated in the following schedule. The kinds and quantities of food in the basal ration, as served for each meal, the character and amount of the supplemental ration in the different experiments, and the quantity of drink consumed at different periods of the day were as follows:

Diet in metabolism experiments Nos. 26–28.

FOOD—BASAL RATION.

	Breakfast.	Dinner.	Supper.	Total.
	Grams.	*Grams.*	*Grams.*	*Grams.*
Beef	35	50	....	85
Butter	10	12	8	30
Milk	300	400	300	1,000
Bread	50	100	50	200
Ginger snaps	....	30	30	60
Parched cereal	25	....	25	50
Sugar [a]	15	....	....	15

[a] Used in alcohol and water in experiment No. 27.

FOOD—SUPPLEMENTAL RATION.

Experiment No. 26.—63.5 grams butter were added to basal ration.
Experiment No. 27.—72 grams absolute alcohol were added to basal ration.
Experiment No. 28.—128 grams sugar were added to basal ration.

DRINK.

Time.	Experiment No. 26.	Experiment No. 27.	Experiment No. 28.
	Water.	Alcohol and sweetened water.	Water.
	Grams.	*Grams.*	*Grams.*
Breakfast	100	150	100
10 a. m	200	125	200
Dinner	....	200	....
3 p. m	200	125	200
Supper	....	175	....
9 p. m	300	112	300
	800	[a] 887	800

[a] Contains 72 grams absolute alcohol and 15 grams sugar.

Daily routine.—The general routine of the experiment was as follows:

Daily programme—Metabolism experiments Nos. 26–28.

6.50 a. m	Take pulse and temperature.
7 a. m	Rise, pass urine, weigh self dressed, weigh absorbers.
7.45 a. m	Breakfast. Drink 100 grams water.
10 a. m	Drink 200 grams water.
12.50 p. m	Take pulse and temperature.
1 p. m	Pass urine.
1.15 p. m	Dinner.
3 p. m	Drink 200 grams water.
6 p. m	Supper.
6.50 p. m	Take pulse and temperature.
7 p. m	Pass urine, weigh self dressed, weigh absorbers.
9 p. m	Drink 300 grams water.
10.20 p. m	Take pulse and temperature.
10.30 p. m	Retire.
1 a. m	Pass urine.

Table LXI summarizes the most important statistics in the diary kept by the subject. The subject weighed himself with clothing twice each day. The reasons for not removing all the clothing in weighing were two: It was desirable to avoid the muscular work involved in dressing and undressing; it has also been found that the sudden increase of radiation of heat from the skin when the clothing is removed causes a decided rise in the temperature inside the chamber, and thus disturbs the accuracy of the heat measurements to some extent. There was extremely little muscular exercise and no sensible perspiration. Hence the differences in weight from time to time must represent very nearly the changes in body weight. The determinations of pulse rate were made, of course, by the subject himself, when either sitting or reclining, after several minutes rest. The measurement at 6.50 a. m., however, was made before rising from bed.

The temperature was determined by a mercury thermometer placed in the axilla. As has already been stated, it was found that the thermometer reached as high a point in 10 minutes as in 15 or 20 minutes. The most of the temperatures, therefore, were made after the thermometer had been in place about 10 minutes. It was our belief at the outset that the body temperatures as thus taken are not perfectly accurate, and this belief has been confirmed by observations with an electrical rectal thermometer, since devised for continuous and accurate observations of internal body temperature.[a] While these axillary determinations of body temperature are not entirely accurate, the later observations with the electrical thermometer lead us to believe that the daily curves for the two are nearly parallel.

In previous experiments an hygrometer had been placed in the chamber, and readings with dry and wet bulb were taken at frequent intervals. Inasmuch, however, as these readings were not used in the computations of results, and it is desirable in rest experiments to avoid all unnecessary exertion, even that of rising and reading the hygrometer, these observations were not made in the experiments of 1900.

TABLE LXI.—*Summary of the diary—Metabolism experiments Nos. 26–28.*

Date and time.	Weight with clothes.	Pulse rate per minute.	Temperature.
1900.			
Experiment No. 26.	*Kilograms.*		°*F.*
Feb. 14, 7 a. m	64.00	68	97.8
8.36 a. m		78	98.3
10.27 a. m		67	98.1
12.27 p. m		64	
12.33 p. m			97.8
12.53 p. m		61	
1 p. m			97.9
2.27 p. m		77	98.5
3.47 p. m			98.5
4.30 p. m		72	98.5
5.30 p. m		67	
5.45 p. m			98.7
6.17 p. m	64.88		
8.13 p. m			97.6
8.30 p. m		64	97.5
9.29 p. m		64	97.7
10.15 p. m		64	
Feb. 15, 6.50 a. m		69	98.1
7 a. m	64.18		
7.34 a. m		78	
7.39 a. m			98.3
8.33 a. m		82	98.5
9.28 a. m		80	
9.30 a. m			98.3
10.33 a. m		71	
10.46 a. m			98.5
11.30 a. m		70	98.1
12.31 p. m		68	
12.37 p. m			98.4
12.54 p. m		68	
1 p. m			98.2
1.59 p. m		75	98.2
2.28 p. m		81	98.5
3.35 p. m		77	98.2
4.28 p. m		76	
4.30 p. m			98.1
5.30 p. m			98.0
5.49 p. m		69	
6.30 p. m		69	98.2
6.55 p. m	64.87	68	98.2
7.30 p. m		75	98.1
8.30 p. m		67	97.6
8.54 p. m		70	
9 p. m			97.5
9.30 p. m		67	
9.35 p. m			97.4
9.51 p. m			97.6
1900—Continued.			
Experiment No. 26—C't'd.	*Kilograms.*		°*F.*
Feb. 15, 10.15 p. m		70	
10.20 p. m			97.5
Feb. 16, 6.55 a. m		71	
7 a. m	64.01		98.1
8.32 a. m		82	
8.40 a. m			98.3
9.30 a. m		79	
9.37 a. m			98.2
10.31 a. m		76	98.3
11.26 a. m		72	
11.30 a. m			98.2
12.27 p. m		70	
12.30 p. m			98.1
12.58 p. m		71	
1 p. m			98.2
2.01 p. m		80	98.2
2.30 p. m		79	98.2
3.35 p. m		81	98.3
4.05 p. m			98.2
4.27 p. m		79	
4.30 p. m			98.2
5.30 p. m		75	98.5
5.43 p. m			98.7
6.32 p. m		80	
6.42 p. m			98.4
7 p. m	64.73	77	98.5
7.34 p. m		75	
7.40 p. m			98.0
7.50 p. m			98.3
8.26 p. m		71	
8.30 p. m			97.8
9.30 p. m		68	97.8
10.19 p. m		65	
10.22 p. m			97.1
Experiment No. 27.			
Feb. 17, 6.55 a. m		69	
7 a. m	64.07		
7.31 a. m		82	
7.35 a. m			97.8
8.32 a. m		89	
8.38 a. m			97.9
9.32 a. m		98	98.1
10.29 a. m		97	
10.30 a. m			98.3
11.30 a. m		87	97.9

[a]See p. 273.

TABLE LXI.—*Summary of the diary—Metabolism experiments Nos. 26–28*—Continued.

Date and time.	Weight with clothes.	Pulse rate per minute.	Temperature.
1900—Continued.			
Experiment No. 27—C't'd.	*Kilograms.*		*°F.*
Feb. 17, 12.30 p. m		80	97.8
1 p. m		77	97.8
1.41 p. m		80	
1.49 p. m			98.0
2 p. m			98.1
2.10 p. m			97.9
2.27 p. m		90	
2.30 p. m			97.8
2.59 p. m		91	
3 p. m			97.9
3.27 p. m		96	
3.30 p. m			98.1
4.27 p. m		94	
4.30 p. m			98.2
5.27 p. m		83	98.1
5.43 p. m		83	
5.46 p. m			98.1
6.30 p. m		84	
6.34 p. m			97.7
6.46 p. m			98.1
6.58 p. m		87	98.0
7 p. m	64.55		
7.30 p. m		90	97.7
7.45 p. m			97.8
8.27 p. m		84	
8.30 p. m			97.5
8.54 p. m		83	
8.55 p. m			97.5
9.28 p. m		79	
9.35 p. m			97.3
9.46 p. m			97.3
10.16 p. m		73	
10.21 p. m			97.1
Feb. 18, 6.55 a. m		72	
7 a. m	63.75		98.1
7.30 a. m		82	
7.34 a. m			97.9
8.40 a. m		90	98.2
9.30 a. m		96	98.4
10.27 a. m		90	
10.30 a. m			98.3
11.31 a. m		82	97.8
11.55 a. m			98.1
12.27 p. m		75	
12.30 p. m			98.1
12.55 p. m		75	98.3
1.42 p. m		83	
1.50 p. m			98.1
2.28 p. m		90	
2.30 p. m			98.4
3.28 p. m		90	
3.30 p. m			98.4
4.30 p. m		90	98.3
5.32 p. m		78	
5.40 p. m			98.3
6.27 p. m		80	
6.30 p. m			98.1
6.56 p. m		81	
6.58 p. m			98.0
7 p. m	64.37		
7.30 p. m		87	97.7
8.34 p. m		80	97.7
9.29 p. m		72	97.4
10 p. m			97.4
10.25 p. m			97.2
10.28 p. m		77	
Feb. 19, 7 a. m		75	98.1
7.31 a. m		85	97.8
8.30 a. m		90	98.0
9.30 a. m		96	98.2

Date and time.	Weight with clothes.	Pulse rate per minute.	Temperature.
1900—Continued.			
Experiment No. 27—C't'd.	*Kilograms.*		*°F.*
Feb. 19, 10.31 a. m		91	98.2
11.27 a. m		81	
11.30 a. m			98.0
12.30 p. m		73	97.7
12.56 p. m		74	
12.59 p. m			98.1
1.33 p. m		81	
1.37 p. m			98.1
2.30 p. m		92	98.3
3.30 p. m		93	98.2
4.30 p. m		88	
4.46 p. m			98.2
5.30 p. m		78	98.2
6.29 p. m		81	
6.33 p. m			98.2
6.59 p. m		85	
7 p. m	64.49		98.1
7.30 p. m		90	
7.35 p. m			97.6
8.27 p. m		83	97.6
9.30 p. m		76	97.3
9.42 p. m			97.5
10.19 p. m		74	97.3
Experiment No. 28.			
Feb. 20, 6.55 a. m		72	
7 a. m	63.71		98.1
7.32 a. m		88	
7.35 a. m			98.4
8.30 a. m		91	
8.31 a. m			98.4
9.30 a. m		99	98.7
10.30 a. m		84	98.4
11.30 a. m		81	98.2
11.36 a. m		78	
12.27 p. m		70	
12.33 p. m			98.1
12.57 p. m		70	
12.59 p. m			98.1
1.52 p. m		81	
1.57 p. m			98.3
3.34 p. m		81	98.2
4.30 p. m		79	98.1
5.32 p. m		71	
5.41 p. m			98.0
6.35 p. m		77	
6.40 p. m			98.1
6.57 p. m		78	
7 p. m	64.32		98.1
7.30 p. m		88	97.8
8.28 p. m		72	
8.30 p. m			97.7
9.30 p. m		67	
9.32 p. m			97.3
10.18 p. m		67	
10.20 p. m			97.2
Feb. 21, 6.55 a. m		73	
7 a. m	63.83		98.1
7.29 a. m		87	
7.30 a. m			98.1
8.29 a. m		92	
8.30 a. m			98.3
9.30 a. m		101	98.3
10.30 a. m		87	
10.33 a. m			98.4
11.27 a. m		78	
11.31 a. m			97.9
12.31 p. m		77	98.1
1 p. m		73	

TABLE LXI.—*Summary of the diary—Metabolism experiments Nos. 26–28*—Continued.

Date and time.	Weight with clothes.	Pulse rate per minute.	Temperature.
1900—Continued.			
Experiment No. 28—C't'd.	*Kilograms.*		*°F.*
Feb. 21, 1.54 p. m.		80	
2.01 p. m.			98.2
2.27 p. m.		93	
2.34 p. m.			98.5
3.52 p. m.		86	
3.54 p. m.			98.2
4.35 p. m.		76	
4.52 p. m.		79	98.2
5.28 p. m.		75	98.5
6.32 p. m.		77	
6.59 p. m.		79	98.2
7 p. m	64.63		
7.31 p. m.		81	97.7
7.41 p. m.			97.9
8.27 p. m.		79	
8.30 p. m.			97.7
9.27 p. m.		73	
9.52 p. m.			97.6
Feb. 22, 6.55 a. m		69	
7 a. m.	63.85		98.1
7.36 a. m		85	
7.40 a. m			97.9
8.28 a. m		93	
8.33 a. m			98.3
9.27 a. m		95	
9.30 a. m			98.2
1900—Continued.			
Experiment No. 28—C't'd.	*Kilograms.*		*°F.*
Feb. 22, 10.29 a. m		87	
10.30 a. m			98.4
11.36 a. m		82	98.0
12.27 p. m.		74	
12.30 p. m.			98.2
12.55 p. m.		70	
12.58 p. m.			98.2
2.07 p. m.		83	
2.15 p. m.			98.6
2.30 p. m.		84	
2.50 p. m.			98.4
3.30 p. m.		84	98.4
4.29 p. m.		78	98.4
5.30 p. m.		73	
5.37 p. m.			98.2
6.30 p. m.		73	98.4
6.57 p. m.	64.77	76	98.1
7.27 p. m.		74	
7.31 p. m.			97.7
8.32 p. m.		72	
8.42 p. m.			97.5
9.27 p. m.		66	
9.30 p. m.			97.3
10.20 p. m.		70	97.1
Feb. 23, 6.55 a. m		76	
7 a. m.	64.05		98.1

Detailed statistics of income and outgo.—The quantities of nutrients in the basal ration, which was the same in all 3 experiments, and the quantities in the supplemental ration in the different experiments of this series are shown in Table LXII. The feces were determined for each experiment in order to obtain data concerning the relative digestibility of the food with the different supplemental rations.

TABLE LXII.—*Weight, composition, and heat of combustion of foods—Metabolism experiments Nos. 26–28.*

Laboratory No.	Food material.	Weight per day.	Water.	Protein.	Fat.	Carbohydrates.	Nitrogen.	Carbon.	Hydrogen.	Heat of combustion.
	Basal ration.	*Grams.*	*Grams.*	*Grams.*	*Grams.*	*Grams.*	*Grams.*	*Grams.*	*Grams.*	*Calories.*
3176	Beef	85.0	53.1	28.7	2.4		4.60	16.62	2.30	187
3177	Butter	30.0	3.0	.5	25.8		.08	19.51	3.01	240
3179	Milk, skimmed	1,000.0	900.0	42.0	3.0	47.0	6.70	46.30	6.30	462
3180	Bread	200.0	78.6	17.8	3.2	97.8	2.84	55.52	7.98	561
3181	Ginger snaps	60.0	2.5	3.7	5.0	47.9	.60	26.59	3.97	266
3168	Parched cereal	50.0	2.8	5.9	.9	39.5	.94	21.10	2.97	207
——	Sugar	15.0				15.0		6.31	.97	59
	Total for 1 day	1,440.0	1,040.0	98.6	40.3	247.2	15.76	191.95	27.50	1,982
	Supplemental ration.									
	EXPERIMENT NO. 26.									
	Butter	63.5	6.3	1.0	54.5		.16	41.29	6.36	508
	Total for 1 day	**1,503.5**	**1,046.3**	**99.6**	**94.8**	**247.2**	**15.92**	**233.24**	**33.86**	**2,490**
	EXPERIMENT NO. 27.									
	Alcohol	72.0						37.56	9.39	509
	Total for 1 day	**1,512.0**	**1,040.0**	**98.6**	**40.3**	**247.2**	**15.76**	**229.51**	**36.89**	**2,491**
	EXPERIMENT NO. 28.									
	Sugar	128.0				128.0		53.88	8.29	507
	Total for 1 day	**1,568.0**	**1,040.0**	**98.6**	**40.3**	**375.2**	**15.76**	**245.83**	**35.79**	**2,489**

TABLE LXIII.—*Weight, composition, and heat of combustion of feces—Metabolism experiments Nos. 26–28.*

Laboratory No.		Weight.	Water.	Protein.	Fat.	Carbohydrates.	Nitrogen.	Carbon.	Hydrogen.	Heat of combustion.
	Experiment No. 26.	*Grams.*	*Grams.*	*Grams.*	*Grams.*	*Grams.*	*Grams.*	*Grams.*	*Grams.*	*Calories.*
3183	Feces for 3 days	236.5	171.0	20.6	8.5	20.1	3.26	28.33	3.41	317
	Average per day	78.8	57.0	6.9	2.8	6.7	1.09	9.44	1.14	106
	Experiment No. 27.									
3184	Feces for 3 days	218.9	152.1	21.0	6.3	21.2	3.35	26.84	2.41	292
	Average per day	73.0	50.7	7.0	2.1	7.1	1.12	8.95	.80	97
	Experiment No. 28.									
3185	Feces for 3 days	219.9	155.2	23.3	12.1	16.1	3.74	29.93	4.02	335
	Average per day	73.3	51.7	7.8	4.0	5.3	1.25	9.98	1.34	112

The urine was collected and the nitrogen determined in the usual 6-hour periods each day. No attempt was made to dry composite samples of the urine for each experiment for the determinations of carbon and hydrogen, but aliquot portions were taken from each day's urine for the preparation of a 9 days' composite sample, which should represent the urine for the total series of experiments. The heats of combustion of the composite sample for each day were, however, determined. Statistics of the urine for experiment No. 27 are given in detail, by 6-hour periods, and those of experiments Nos. 26 and 28, in which alcohol did not form a part of the diet, are summarized by days, for comparison.

TABLE LXIV.—*Amount, specific gravity, and nitrogen of urine, by 6-hour periods—Metabolism experiments Nos. 26–28.*

Date.	Period.	Amount.	Specific gravity.	Nitrogen.	
	Experiment No. 26.				
1900.		*Grams.*		*Per cent.*	*Grams.*
Feb. 14–15	7 a. m. to 7 a. m.	1,216.5	1.021	1.38	16.63
15–16	7 a. m. to 7 a. m.	1,526.1	1.0175	.99	15.08
16–17	7 a. m. to 7 a. m.	1,340.4	1.0185	1.08	14.44
	Experiment No. 27.				
17	7 a. m. to 1 p. m.	378.5	1.0175	.94	3.56
17	1 p. m. to 7 p. m.	576.2	1.0135	.71	4.09
17–18	7 p. m. to 1 a. m.	269.0	1.021	1.38	3.71
18	1 a. m. to 7 a. m.	297.0	1.018	1.09	3.24
	Total	1,520.7	....	....	14.60
	Total by composite	1,520.7	1.017	.96	14.60
18	7 a. m. to 1 p. m.	537.9	1.014	.79	4.25
18	1 p. m. to 7 p. m.	444.6	1.016	.97	4.32
18–19	7 p. m. to 1 a. m.	281.3	1.021	1.41	3.97
19	1 a. m. to 7 a. m.	172.6	1.0245	1.73	2.99
	Total	1,436.4	....	....	15.53
	Total by composite	1,436.4	1.018	1.08	15.51
19	7 a. m. to 1 p. m.	291.0	1.0215	1.47	4.28
19	1 p. m. to 7 p. m.	473.0	1.015	1.03	4.87
19–20	7 p. m. to 1 a. m.	310.9	1.019	1.36	4.23
20	1 a. m. to 7 a. m.	219.3	1.0215	1.55	3.40
	Total	1,294.2	....	....	16.78
	Total by composite	1,294.2	1.018	1.30	16.82
	Experiment No. 28.				
20–21	7 a. m. to 7 a. m.	1,169.8	1.020	1.36	15.90
21–22	7 a. m. to 7 a. m.	1,292.2	1.017	1.18	15.23
22–23	7 a. m. to 7 a. m.	1,202.5	1.018	1.22	14.65

TABLE LXV.—*Daily elimination of carbon, hydrogen, and water in the urine—Metabolism experiments Nos. 26–28.*

Date.	Amount.	Carbon.		Hydrogen.		Water.		Heat of combustion.	
								Per gram.	Total.
1900.									
Experiment No. 26.	*Grams.*	*Per cent.*	*Grams.*	*Per cent.*	*Grams.*	*Per cent.*	*Grams.*	*Calories.*	*Calories.*
Feb. 14–15	1,216.5	....	11.93	....	2.87	....	1,157.3	0.103	125
15–16	1,526.1	....	10.82	....	2.61	....	1,472.4	.082	125
16–17	1,340.4	....	10.36	....	2.50	....	1,289.0	.101	135
	4,083.0	....	33.11	....	7.98	....	3,918.7	....	385
Experiment No. 27.									
Feb. 17–18	1,520.7	....	10.47	....	2.52	....	1,468.7	.073	111
18–19	1,436.4	....	11.14	....	2.69	....	1,381.1	.084	121
19–20	1,294.2	....	12.04	....	2.90	....	1,234.5	.108	140
	4,251.3	....	33.65	....	8.11	....	4,084.3	....	372
Experiment No. 28.									
Feb. 20–21	1,169.8	....	11.40	....	2.75	....	1,113.2	.102	119
21–22	1,292.2	....	10.92	....	2.63	....	1,238.0	.103	133
22–23	1,202.5	....	10.51	....	2.53	....	1,150.3	.110	132
	3,664.5	....	32.83	....	7.91	....	3,501.5	....	384
Total, 9 days	11,998.8	.83	99.59	.20	24.00	95.88	11,504.5	.095	1,141

Tables LXVI–LXVIII show the quantities of carbon dioxid and water found in the ventilating air current in this series of experiments. These statistics are given in detail for the 3 days of experiment No. 27, in which alcohol formed a part of the diet, and are summarized by days for experiments Nos. 26 and 28.

TABLE LXVI.—*Comparison of residual amounts of carbon dioxid and water in the chamber at the beginning and end of each period, and the corresponding gain or loss—Metabolism experiment No. 27.*

Date.	End of period.	Carbon dioxid.		Water.[a]		
		Total amount in chamber.	Gain (+) or loss (−) over preceding period.	Total amount of vapor remaining in chamber.	Gain (+) or loss (−) over preceding period.	Total amount gained (+) or lost (−) during the period.
1900.		*Grams.*	*Grams.*	*Grams.*	*Grams.*	*Grams.*
Feb. 17	7 a. m	23.0	....	31.4	....	....
17	1 p. m	33.1	+10.1	37.1	+5.7	+5.7
17	7 p. m	37.8	+ 4.7	38.6	+1.5	+1.5
18	1 a. m	23.6	−14.2	34.8	−3.8	−3.8
18	7 a. m	27.0	+ 3.4	33.3	−1.5	−1.5
		....	+ 4.0	....	+1.9	+1.9
18	1 p. m	31.0	+ 4.0	37.2	+3.9	+3.9
18	7 p. m	36.5	+ 5.5	37.8	+0.6	+0.6
19	1 a. m	24.1	−12.4	35.3	−2.5	−2.5
19	7 a. m	25.3	+ 1.2	31.0	−4.3	−4.3
		....	− 1.7	....	−2.3	−2.3
19	1 p. m	31.0	+ 5.7	37.1	+6.1	+6.1
19	7 p. m	39.1	+ 8.1	39.0	+1.9	+1.9
20	1 a. m	23.0	−16.1	35.5	−3.5	−3.5
20	7 a. m	26.4	+ 3.4	32.9	−2.6	−2.6
		....	+ 1.1	....	+1.9	+1.9
		....	+ 3.4	....	+1.5	....

[a] There was no change in weight of absorbers and no drip in this experiment.

TABLE LXVII.—*Record of carbon dioxid in ventilating air current—Metabolism experiments Nos. 26–28.*

Date.	Period.	(a) Ventilation. Number of liters of air.	Carbon dioxid. In incoming air. (b) Per liter.	(c) Total, a×b.	(d) In outgoing air.	(e) Total excess in outgoing air, d−c.	(f) Correction for amount remaining in chamber.	(g) Corrected amount exhaled by subject, e+f.	(h) Total weight of carbon exhaled, g×3/11
1900.	*Experiment No. 26.*	*Liters.*	*Mg.*	*Grams.*	*Grams.*	*Grams.*	*Grams.*	*Grams.*	*Grams.*
Feb. 14–15	7 a. m. to 7 a. m	116, 602	....	64. 7	776. 3	711. 6	+ 3. 1	714. 7	194. 9
15–16	7 a. m. to 7 a. m	118, 158	....	65. 7	795. 9	730. 2	− 2. 7	727. 5	198. 4
16–17	7 a. m. to 7 a. m	119, 712	....	67. 7	782. 0	714. 3	+ 0. 4	714. 7	194. 9
	Experiment No. 27.								
17	7 a. m. to 1 p. m	29, 540	0. 567	16. 8	217. 6	200. 8	+10. 1	210. 9	57. 5
17	1 p. m. to 7 p. m	27, 207	. 610	16. 6	215. 5	198. 9	+ 4. 7	203. 6	55. 5
17–18	7 p. m. to 1 a. m	29, 540	. 561	16. 6	206. 3	189. 7	−14. 2	175. 5	47. 9
18	1 a. m. to 7 a. m	28, 762	. 554	15. 9	146. 2	130. 3	+ 3. 4	133. 7	36. 5
	Total	115, 049	....	65. 9	785. 6	719. 7	+ 4. 0	723. 7	197. 4
18	7 a. m. to 1 p. m	28, 762	. 559	16. 1	220. 8	204. 7	+ 4. 0	208. 7	56. 9
18	1 p. m. to 7 p. m	28, 762	. 551	15. 8	214. 5	198. 7	+ 5. 5	204. 2	55. 7
18–19	7 p. m. to 1 a. m	29, 540	. 537	15. 9	206. 2	190. 3	−12. 4	177. 9	48. 5
19	1 a. m. to 7 a. m	29, 540	. 548	16. 2	147. 5	131. 3	+ 1. 2	132. 5	36. 1
	Total	116, 604	....	64. 0	789. 0	725. 0	− 1. 7	723. 3	197. 2
19	7 a. m. to 1 p. m	27, 208	. 548	14. 9	209. 5	194. 6	+ 5. 7	200. 3	54. 6
19	1 p. m. to 7 p. m	27, 985	. 575	16. 1	218. 5	202. 4	+ 8. 1	210. 5	57. 4
19–20	7 p. m. to 1 a. m	29, 540	. 573	16. 9	220. 1	203. 2	−16. 1	187. 1	51. 0
20	1 a. m. to 7 a. m	28, 762	. 551	15. 8	149. 2	133. 4	+ 3. 4	136. 8	37. 3
	Total	113, 495	....	63. 7	797. 3	733. 6	+ 1. 1	734. 7	200. 3
	Experiment No. 28.								
20–21	7 a. m. to 7 a. m	112, 717	....	64. 3	840. 3	776. 0	− 2. 3	773. 7	211. 0
21–22	7 a. m. to 7 a. m	108, 830	....	67. 6	843. 3	775. 7	+ 4. 8	780. 5	212. 8
22–23	7 a. m. to 7 a. m	111, 162	....	66. 4	830. 6	764. 2	− 0. 2	764. 0	208. 3

TABLE LXVIII.—*Record of water in ventilating air current—Metabolism experiments Nos. 26–28.*

Date.	Period.	(a) Ventilation. Number of liters of air.	Water in incoming air. (b) Per liter.	(c) Total, a×b.	Water in outgoing air. (d) Amount condensed in freezers.	(e) Amount not condensed in freezers.	(f) Total, d−c.	(g) Total excess water in outgoing air, f−c.	(h) Correction for water remaining in chamber.	(i) Total water of respiration and perspiration, g+h.
1900.	*Experiment No. 26.*	*Liters.*	*Mg.*	*Grams.*	*Grams.*	*Grams.*	*Grams.*	*Grams.*	*Grams.*	*Grams.*
Feb. 14–15	7 a. m. to 7 a. m	116, 602	......	97. 1	749. 3	179. 6	928. 9	831. 8	−2. 7	829. 1
15–16	7 a. m. to 7 a. m	118, 158	......	101. 8	734. 3	175. 4	909. 7	807. 9	−1. 3	806. 6
16–17	7 a. m. to 7 a. m	119, 712	......	97. 8	724. 9	173. 3	898. 2	800. 4	−0. 9	799. 5
	Experiment No. 27.									
17	7 a. m. to 1 p. m	29, 540	. 820	24. 2	183. 9	42. 5	226. 4	202. 2	+5. 7	207. 9
17	1 p. m. to 7 p. m	27, 207	. 821	22. 3	193. 7	38. 0	231. 7	209. 4	+1. 5	210. 9
17–18	7 p. m. to 1 a. m	29, 540	. 829	24. 5	184. 7	45. 2	229. 9	205. 4	−3. 8	201. 6
18	1 a. m. to 7 a. m	28, 762	. 828	23. 8	166. 4	39. 0	205. 4	181. 6	−1. 5	180. 1
	Total	115, 049	......	94. 8	728. 7	164. 7	893. 4	798. 6	+1. 9	800. 5
18	7 a. m. to 1 p. m	28, 762	. 817	23. 5	194. 5	43. 6	238. 1	214. 6	+3. 9	218. 5
18	1 p. m. to 7 p. m	28, 762	. 800	23. 0	194. 5	41. 0	235. 5	212. 5	+0. 6	213. 1
18–19	7 p. m. to 1 a. m	29, 540	. 818	24. 2	185. 5	43. 8	229. 3	205. 1	−2. 5	202. 6
19	1 a. m. to 7 a. m	29, 540	. 800	23. 6	172. 0	39. 4	211. 4	187. 8	−4. 3	183. 5
	Total	116, 604	......	94. 3	746. 5	167. 8	914. 3	820. 0	−2. 3	817. 7

TABLE LXVIII.—*Record of water in ventilating air current—Metabolism experiments Nos. 26–28*—Continued.

Date.	Period.	(*a*) Ventilation. Number of liters of air.	Water in incoming air. (*b*) Per liter.	(*c*) Total, *a*×*b*.	Water in outgoing air. (*d*) Amount condensed in freezers.	(*e*) Amount not condensed in freezers.	(*f*) Total, *d*+*e*.	(*g*) Total excess water in outgoing air, *f*−*c*.	(*h*) Correction for water remaining in chamber.	(*i*) Total water of respiration and perspiration. *g*+*h*.
	Experiment No. 27—Continued.									
1900.		*Liters.*	*Mg.*	*Grams.*	*Grams.*	*Grams.*	*Grams.*	*Grams.*	*Grams.*	*Grams.*
Feb. 19	7 a. m. to 1 p. m	27,208	.810	22.0	184.3	39.6	223.9	201.9	+6.1	208.0
19	1 p. m. to 7 p. m	27,985	.826	23.1	191.2	38.2	229.4	206.3	+1.9	208.2
19–20	7 p. m. to 1 a. m	29,540	.837	24.7	195.2	45.9	241.1	216.4	−3.5	212.9
20	1 a. m. to 7 a. m	28,762	.819	23.6	173.3	39.0	212.3	188.7	−2.6	186.1
	Total	113,495	......	93.4	744.0	162.7	906.7	813.3	+1.9	815.2
	Experiment No. 28.									
20–21	7 a. m. to 7 a. m	112,717	......	94.8	769.8	163.7	933.5	838.7	−2.1	836.6
21–22	7 a. m. to 7 a. m	108,830	......	90.2	742.4	156.9	899.3	809.1	+4.7	813.8
22–23	7 a. m. to 7 a. m	111,162	......	97.9	730.7	159.9	890.6	792.7	−2.1	790.6

The heat carried away by the water current and the latent heat of vaporization of water in this series of experiments are shown in Table LXIX. As in the previous tables, the data are summarized for experiments Nos. 26 and 28 and given in detail for experiment No. 27, in which alcohol formed a part of the diet.

TABLE LXIX.—*Summary of calorimetric measurements—Metabolism experiments Nos. 26–28.*

Date.	Period.	(*a*) Heat measured in terms of C_{20}.	(*b*) Change of temperature of calorimeter.	(*c*) Capacity correction of calorimeter $b \times 60$.	(*d*) Correction due to temperature of food and dishes.	(*e*) Water vaporized equals total amount exhaled less amount condensed in chamber.	(*f*) Heat used in vaporization of water $e \times 0.592$.	(*g*) Total heat determined $a+c+d+f$.
	Experiment No. 26.							
1900.		*Calories.*	*Degrees.*	*Calories.*	*Calories.*	*Grams.*	*Calories.*	*Calories.*
Feb. 14–15	7 a. m. to 7 a. m	1,584.1	+0.1	+0.60	+ 1.7	829.1	490.8	2,077.2
15–16	7 a. m. to 7 a. m	1,618.3	+ .3	+1.80	+ 2.5	806.6	477.5	2,100.1
16–17	7 a. m. to 7 a. m	1,592.3	+ .1	+ .60	+12.0	799.5	473.3	2,078.2
	Experiment No. 27.							
17	7 a. m. to 1 p. m	513.1	+ .1	+ .60	− 3.1	207.9	123.1	633.7
17	1 p. m. to 7 p. m	477.5	0	0	− 9.3	210.9	124.8	593.0
17–18	7 p. m. to 1 a. m	404.6	0	0	+ 1.0	201.6	119.3	524.9
18	1 a. m. to 7 a. m	256.8	+ .1	+ .60	....	180.1	106.6	364.0
	Total	1,652.0	+ .2	+1.20	−11.4	800.5	473.8	2,115.6
18	7 a. m. to 1 p. m	527.4	0	0	− 8.2	218.5	129.3	648.5
18	1 p. m. to 7 p. m	481.6	0	0	− 9.6	213.1	126.2	598.2
18–19	7 p. m. to 1 a. m	402.2	− .1	− .60	+ 4.3	202.6	119.9	525.8
19	1 a. m. to 7 a. m	243.9	+ .1	+ .60	....	183.5	108.6	353.1
	Total	1,655.1	0	0	−13.5	817.7	484.0	2,125.6
19	7 a. m. to 1 p. m	515.5	0	0	− 8.4	208.0	123.1	630.2
19	1 p. m. to 7 p. m	467.9	0	0	− 7.1	208.2	123.2	584.0
19–20	7 p. m. to 1 a. m	403.7	0	0	+ 3.7	212.9	126.0	533.4
20	1 a. m. to 7 a. m	269.5	+ .1	+ .60	....	186.1	110.2	380.3
	Total	1,656.6	+ .1	+ .60	−11.8	815.2	482.5	2,127.9
	Experiment No. 28.							
20–21	7 a. m. to 7 a. m	1,599.5	0	0	+ 2.8	836.6	495.2	2,097.5
21–22	7 a. m. to 7 a. m	1,589.7	+ .2	+1.20	+ 2.6	813.8	481.8	2,075.3
22–23	7 a. m. to 7 a. m	1,594.2	+ .1	+ .60	+ 2.2	790.6	468.0	2,065.0

The determinations of alcohol in urine and freezer water and of reducing material reckoned as alcohol in the air current were made in the usual manner, and the results are given in Table LXX. It will be observed that there was an elimination of reducing material equivalent to an average of 0.32 gram of alcohol per day on the 6 days of experiments Nos. 26 and 28. This amount has been deducted from the values obtained in experiment No. 27, and the difference is taken as a measure of the alcohol excreted unoxidized. It will likewise be observed that there is here no indication whatever of any lag in the elimination of alcohol from the body as was apparently indicated by the results obtained in experiments Nos. 18–20.

TABLE LXX.—*Alcohol ingested and excreted—Metabolism experiment No. 27.*

Date.	Alcohol ingested.	Alcohol excreted, including other reducing material calculated as alcohol. In urine (distillate).	In freezer water (distillate).	In air current.	Total.	Alcohol excreted unoxidized.[a]	Alcohol metabolized in body.	
1900.								
Experiment No. 26.	*Grams.*	*Grams.*	*Grams.*	*Grams.*	*Grams.*	*Grams.*	*Grams.*	*Per cent.*
Feb. 14–15	....	0.02	0.01	0.33	0.36	....	....	....
15–16	....	.03	Trace.	.28	.31	....	....	....
16–17	....	.02	Trace.	.45	.47	....	....	....
Experiment No. 27.								
Feb. 17–18	72	.13	.01	1.23	1.37	1.05	70.9	98.5
18–19	72	.11	.01	1.04	1.16	.84	71.2	98.9
19–20	72	.09	.01	.98	1.08	.76	71.2	98.9
Total	216	.33	.03	3.25	3.61	2.65	213.3	....
Average for day	72	.11	.01	1.08	1.20	.88	71.1	98.8
Experiment No. 28.								
Feb. 20–21	....	.02	Trace.	.29	.31	....	....	....
21–22	....	.02	.01	.19	.22	....	....	....
22–23	....	.01	.01	.21	.23	....	....	....

[a] Equals total reducing material excreted less 0.32 grams of reducing material not alcohol, the average for the days on which no alcohol was consumed.

Balance of income and outgo of matter and energy.—Tables LXXI to LXXIV summarize the income and outgo of nitrogen, carbon, hydrogen, and energy according to the plan adopted in previous experiments.

TABLE LXXI.—*Income and outgo of nitrogen and carbon—Metabolism experiments Nos. 26–28.*

Date and period.	Nitrogen. (a) In food.	(b) In feces.	(c) In urine.	(d) Gain (+) or loss (−) $a-(b+c)$.	Carbon. (e) In food.	(f) In feces.	(g) In urine.	(h) In respiratory products.	(i) In alcohol eliminated.	(k) Gain (+) or loss (−) $e-(f+g+h+i)$.
1900.										
Experiment No. 26.	*Grams.*	*Grams.*	*Grams.*	*Grams.*	*Grams.*	*Grams.*	*Grams.*	*Grams.*	*Grams.*	*Grams.*
Feb. 14–15, 7 a. m. to 7 a. m.	15.9	1.1	16.6	−1.8	233.2	9.4	11.9	194.9	....	+17.0
15–16, 7 a. m. to 7 a. m.	15.9	1.1	15.1	− .3	233.2	9.5	10.8	198.4	....	+14.5
16–17, 7 a. m. to 7 a. m.	15.9	1.1	14.4	+ .4	233.2	9.4	10.4	194.9	....	+18.5
Total	47.7	3.3	46.1	−1.7	699.6	28.3	33.1	588.2	....	+50.0
Average per day	15.9	1.1	15.4	− .6	233.2	9.4	11.0	196.1	....	+16.7

TABLE LXXI.—*Income and outgo of nitrogen and carbon—Metabolism experiments Nos. 26–28*—Continued.

Date and period.	Nitrogen. (a) In food.	Nitrogen. (b) In feces.	Nitrogen. (c) In urine.	Nitrogen. (d) Gain (+) or loss (−) $a-(b+c)$.	Carbon. (e) In food.	Carbon. (f) In feces.	Carbon. (g) In urine.	Carbon. (h) In respiratory products.	Carbon. (i) In alcohol eliminated.	Carbon. (k) Gain (+) or loss (−) $e-(f+g+h+i)$.
1900.										
Experiment No 27.	*Grams.*	*Grams.*	*Grams.*	*Grams.*	*Grams.*	*Grams.*	*Grams.*	*Grams.*	*Grams.*	*Grams.*
Feb. 17–18, 7 a. m. to 7 a. m.	15.8	1.1	14.6	+ .1	229.5	8.9	10.5	197.4	0.5	+12.2
18–19, 7 a. m. to 7 a. m.	15.7	1.1	15.5	− .9	229.5	9.0	11.1	197.2	0.4	+11.8
19–20, 7 a. m. to 7 a. m.	15.8	1.1	16.8	−2.1	229.5	8.9	12.0	200.3	0.4	+ 7.9
Total	47.3	3.3	46.9	−2.9	688.5	26.8	33.6	594.9	1.3	+31.9
Average per day	15.8	1.1	15.7	−1.0	229.5	8.9	11.2	198.3	.5	+10.6
Experiment No. 28.										
Feb. 20–21, 7 a. m. to 7 a. m.	15.8	1.2	15.9	−1.3	245.8	10.0	11.4	211.0	....	+13.4
21–22, 7 a. m. to 7 a. m.	15.7	1.3	15.2	− .8	245.8	10.0	10.9	212.8	....	+12.1
22–23, 7 a. m. to 7 a. m.	15.8	1.2	14.7	− .1	245.8	10.0	10.5	208.3	....	+17.0
Total	47.3	3.7	45.8	−2.2	737.4	30.0	32.8	632.1	....	+42.5
Average per day	15.8	1.2	15.3	− .7	245.8	10.0	10.9	210.7	....	+14.2

TABLE LXXII.—*Income and outgo of water and hydrogen—Metabolism experiments Nos. 26–28.*

Date and period.	Water. (a) In food.	Water. (b) In drink.	Water. (c) In feces.	Water. (d) In urine.	Water. (e) In respiratory products.	Water. (f) Apparent loss $a+b-(c+d+e)$.	Hydrogen. (g) In food.	Hydrogen. (h) In feces.	Hydrogen. (i) In urine.	Hydrogen. (k) In alcohol eliminated.	Hydrogen. (l) Apparent gain $g-(h+i+k)$.	Hydrogen. (m) Loss from water $f \div 9$.	Hydrogen. (n) Total gain (+) or loss (−) $l+m$.
1900.													
Experiment No. 26.	*Grams.*	*Grams.*	*Grams.*	*Grams.*	*Grams.*	*Grams.*	*Grams.*	*Gms.*	*Gms.*	*Gms.*	*Grams.*	*Grams.*	*Grams.*
Feb. 14–15, 7 a. m. to 7 a. m	1,046.3	800.0	57.0	1,157.3	829.1	− 197.1	33.9	1.1	2.9	.....	+29.9	− 21.9	+ 8.0
Feb. 15–16, 7 a. m. to 7 a. m	1,046.3	800.0	57.0	1,472.4	806.6	− 489.7	33.8	1.2	2.6	.....	+30.0	− 54.4	−24.4
Feb. 16–17, 7 a. m. to 7 a. m	1,046.3	800.0	57.0	1,289.0	799.5	− 299.2	33.9	1.1	2.5	.....	+30.3	− 33.2	− 2.9
Total	3,138.9	2,400.0	171.0	3,918.7	2,435.2	− 986.0	101.6	3.4	8.0	.....	+90.2	−109.5	−19.3
Average per day	1,046.3	800.0	57.0	1,306.2	811.7	− 328.6	33.9	1.1	2.7	.....	+30.1	− 36.5	− 6.4
Experiment No. 27.													
Feb. 17–18; 7 a. m. to 7 a. m	1,040.0	800.0	50.7	1,468.7	800.5	− 479.9	36.9	.8	2.5	0.1	+33.5	− 53.3	−19.8
Feb. 18–19, 7 a. m. to 7 a. m	1,040.0	800.0	50.7	1,381.1	817.7	− 409.5	36.9	.8	2.7	.1	+33.3	− 45.5	−12.2
Feb. 19–20, 7 a. m. to 7 a. m	1,040.0	800.0	50.7	1,234.5	815.2	− 260.4	36.9	.8	2.9	.1	+33.1	− 28.9	+ 4.2
Total	3,120.0	2,400.0	152.1	4,084.3	2,433.4	−1,149.8	110.7	2.4	8.1	.3	+99.9	−127.7	−27.8
Average per day	1,040.0	800.0	50.7	1,361.4	811.1	− 383.2	36.9	.8	2.7	.1	+33.3	− 42.6	− 9.3
Experiment No. 28.													
Feb. 20–21, 7 a. m. to 7 a. m	1,040.0	800.0	51.7	1,113.2	836.6	− 161.5	35.8	1.3	2.8	.....	+31.7	− 17.9	+13.8
Feb. 21–22, 7 a. m. to 7 a. m	1,040.0	800.0	51.8	1,238.0	813.8	− 263.6	35.8	1.4	2.6	.....	+31.8	− 29.3	+ 2.5
Feb. 22–23, 7 a. m. to 7 a. m	1,040.0	800.0	51.7	1,150.3	790.6	− 152.6	35.8	1.3	2.5	.....	+32.0	− 17.0	+15.0
Total	3,120.0	2,400.0	155.2	3,501.5	2,441.0	− 577.7	107.4	4.0	7.9	.....	+95.5	− 64.2	+31.3
Average per day	1,040.0	800.0	51.7	1,167.2	813.7	− 192.6	35.8	1.3	2.7	.....	+31.8	− 21.4	+10.4

TABLE LXXIII.—*Gain or loss of protein (N.×6.25), fat, and water—Metabolism experiments Nos. 26–28.*

Date and period.	(a) Nitrogen gained (+) or lost (−).	(b) Protein gained (+) or lost (−) a×6.25.	(c) Total carbon gained (+) or lost (−).	(d) Carbon in protein gained (+) or lost (−) b×.53.	(e) Carbon in fat, etc., gained (+) or lost (−) c−d.	(f) Fat gained (+) or lost (−) e÷.761.	(g) Total hydrogen gained (+) or lost (−).	(h) Hydrogen in protein gained (+) or lost (−) b×.07.	(i) Hydrogen in fat gained (+) or lost (−) f×.118.	(k) Hydrogen in water, etc., gained (+) or lost (−) g−(h+i).	(l) Water gained (+) or lost (−) k×9.
1900.											
Experiment No. 26.	*Grams.*	*Grams.*	*Grams.*	*Grams.*	*Grams.*	*Grams.*	*Grams.*	*Grams.*	*Grams.*	*Grams.*	*Grams.*
Feb. 14–15, 7 a. m. to 7 a. m.	−1.8	−11.2	+17.0	−5.9	+22.9	+30.1	+ 8.0	− .8	+3.6	+ 5.2	+ 46.8
15–16, 7 a. m. to 7 a. m.	− .3	− 1.9	+14.5	−1.0	+15.5	+20.4	−24.4	− .1	+2.4	−26.7	−240.3
16–17, 7 a. m. to 7 a. m.	+ .4	+ 2.5	+18.5	+1.3	+17.2	+22.6	− 2.9	+ .2	+2.7	− 5.8	− 52.2
Total	−1.7	−10.6	+50.0	−5.6	+55.6	+73.1	−19.3	− .7	+8.7	−27.3	−245.7
Average per day	− .6	− 3.5	+16.7	−1.8	+18.5	+24.4	− 6.4	− .2	+2.9	− 9.1	− 81.9
Experiment No. 27.											
Feb. 17–18, 7 a. m. to 7 a. m.	+ .1	+ .6	+12.2	+ .3	+11.9	+15.6	−19.8	......	+1.9	−21.7	−195.3
18–19, 7 a. m. to 7 a. m.	− .9	− 5.6	+11.8	−3.0	+14.8	+19.4	−12.2	− .4	+2.3	−14.1	−126.9
19–20, 7 a. m. to 7 a. m.	−2.1	−13.1	+ 7.9	−6.9	+14.8	+19.5	+ 4.2	− .9	+2.3	+ 2.8	+ 25.2
Total	−2.9	−18.1	+31.9	−9.6	+41.5	+54.5	−27.8	−1.3	+6.5	−33.0	−297.0
Average per day	−1.0	− 6.0	+10.6	−3.2	+13.8	+18.2	− 9.3	− .4	+2.1	−11.0	− 99.0
Experiment No. 28.											
Feb. 20–21, 7 a. m. to 7 a. m.	−1.3	− 8.1	+13.4	−4.3	+17.7	+23.3	+13.8	− .6	+2.7	+11.7	+105.3
21–22, 7 a. m. to 7 a. m.	− .8	− 5.0	+12.1	−2.7	+14.8	+19.4	+ 2.5	− .3	+2.3	+ .5	+ 4.5
22–23, 7 a. m. to 7 a. m.	− .1	− .6	+17.0	− .3	+17.3	+22.7	+15.0	......	+2.7	+12.3	+110.7
Total	−2.2	−13.7	+42.5	−7.3	+49.8	+65.4	+31.3	− .9	+7.7	+24.5	+220.5
Average per day	− .7	− 4.5	+14.2	−2.4	+16.6	+21.8	+10.4	− .3	+2.5	+ 8.2	+ 73.5

TABLE LXXIV.—*Income and outgo of energy—Metabolism experiments Nos. 26–28.*

Date and period.	(a) Heat of combustion of food eaten.	(b) Heat of combustion of feces.	(c) Heat of combustion of urine.	(m) Heat of combustion of alcohol eliminated.	(d) Estimated heat of combustion of protein gained (+) or lost (−).	(e) Estimated heat of combustion of fat gained (+) or lost (−).	(f) Estimated energy of material oxidized in the body. a−(b+c+m+d+e.)	(g) Heat determined.	Heat determined greater (+) or less (−) than estimated. (h) f−g.	(i) h÷f.
1900.										
Experiment No. 26.	*Calories.*	*Calories.*	*Calories.*	*Calories.*	*Calories.*	*Calories.*	*Calories.*	*Calories.*	*Calories.*	*Per cent.*
Feb. 14–15, 7 a. m. to 7 a. m.	2,490	106	125	....	− 64	+287	2,036	2,077	+ 41	+2.0
15–16, 7 a. m. to 7 a. m.	2,490	106	125	....	− 11	+195	2,075	2,100	+ 25	+1.2
16–17, 7 a. m. to 7 a. m.	2,490	106	135	....	+ 14	+216	2,019	2,078	+ 59	+2.9
Total	7,470	318	385	....	− 61	+698	6,130	6,255	+125	....
Average per day	2,490	106	128	....	− 20	+233	2,043	2,085	+ 42	+2.0
Experiment No. 27.										
Feb. 17–18, 7 a. m. to 7 a. m.	2,491	97	111	7	+ 3	+149	2,124	2,116	− 8	− .4
18–19, 7 a. m. to 7 a. m.	2,491	97	121	6	− 32	+185	2,114	2,126	+ 12	+ .6
19–20, 7 a. m. to 7 a. m.	2,491	97	140	5	− 75	+186	2,138	2,128	− 10	− .5
Total	7,473	291	372	18	−104	+520	6,376	6,370	− 6	....
Average per day	2,491	97	124	6	− 35	+174	2,125	2,123	− 2	− .1
Experiment No. 28.										
Feb. 20–21, 7 a. m. to 7 a. m.	2,489	112	119	....	− 47	+222	2,083	2,097	+ 14	+ .7
21–22, 7 a. m. to 7 a. m.	2,489	112	133	....	− 29	+185	2,088	2,075	− 13	− .6
22–23, 7 a. m. to 7 a. m.	2,489	112	132	....	− 3	+217	2,031	2,065	+ 34	+1.7
Total	7,467	336	384	....	− 79	+624	6,202	6,237	+ 35	....
Average per day	2,489	112	128	....	− 26	+208	2,067	2,079	+ 12	+ .6

EXPERIMENTS NOS. 29–31—WORK. NO. 30 WITH ALCOHOL DIET.

Subject.—J. F. S., who served as the subject of the previous series of rest experiments Nos. 26–28. His weight with underclothing was about 64.5 kilograms (142 pounds).

Occupation during experiment.—Work, 8 hours a day, upon a stationary bicycle arranged as an ergometer, as described on page 237.

Duration.—This experiment was the second of a series of 3, each of which continued 3 days. The preliminary period continued 4 days, beginning with breakfast March 12, 1900. On the evening of the fourth day, March 15, the subject entered the calorimeter. The first of the 3 series of experiments, No. 29, began at 7 a. m. March 16, and continued until 7 a. m. March 19, when experiment No. 30 began and continued until 7 a. m. March 22, and in turn was followed by experiment No. 31, which continued until 7 a. m. March 25. The subject therefore remained in the respiration chamber 9 days and 10 nights.

Diet.—The object of this series of experiments was to study the relative replacing power of isodynamic quantities of sugar, alcohol, and fat, when the subject was at active exercise. There was a basal ration, as in the previous series, which was practically the same in the 3 experiments, the only difference being that due to slight variations in the composition of the milk consumed. It furnished, approximately, 100 grams of protein and from 2,949 to 2,984 calories of energy per day in the different periods. To this ration was added, in experiment No. 29, 128 grams of cane sugar per day, furnishing 507 calories of energy. In experiment No. 30 the supplemental ration consisted of 72 grams of absolute alcohol per day, furnishing 509 calories of energy. In experiment No. 31 the supplemental ration consisted of 63.5 grams of butter per day, furnishing 1 gram of protein and 511 calories of energy.

To 795.5 grams of water sweetened with 25 grams of sugar were added 79.5 grams of 90.6 per cent commercial alcohol containing 72 grams absolute alcohol. This alcohol mixture was taken with and between meals in experiment No. 30 as in previous experiments. The sugar in experiment No. 29 was likewise taken with and between meals, but the butter in experiment No. 31 was consumed with the rest of the food in approximately equal portions at breakfast, dinner, and supper. The same amount of water was given in the drink on each day of the experiment and amounted to 1,250 grams per day. In experiment No. 30, 803 grams of this water was furnished by the alcohol mixture. The kinds and quantities of food served at each meal and the quantities of drink at different periods of the day were as follows:

Diet in metabolism experiments Nos. 29–31.

FOOD—BASAL RATION.

	Breakfast.	Dinner.	Supper.	Total.
	Grams.	*Grams.*	*Grams.*	*Grams.*
Beef	....	58	....	58
Butter	12	23	12	47
Milk, whole	300	300	300	900
Bread	75	150	75	300
Ginger snaps	25	25	25	75
Parched cereal	37.5	....	37.5	75
Sugar [a]	12.5	....	12.5	25

[a] Eaten on parched cereal in experiments Nos. 29 and 31; added to water and alcohol in experiment No. 30.

FOOD—SUPPLEMENTAL RATION.

Experiment No. 29, March 16–18.—128 grams of cane sugar daily in the form of loaf sugar, taken with and between meals. This amount also supplemented the basal ration during the preliminary experiment March 12–15.

Experiment No. 30, March 19–21.—72 grams absolute alcohol daily. This required 79.5 grams of 90.57 per cent alcohol, which was made up to 900 grams with the addition of 25 grams sugar and the rest water.

Experiment No. 31, March 22–24.—The additional energy during this experiment was furnished by 63.5 grams butter.

Diet in metabolism experiments Nos. 29–31.

DRINK.

	Experiment No. 29.	Experiment No. 30.		Experiment No. 31.
	Water.	Alcohol and sweetened water.	Water.	Water.
	Grams.	*Grams.*	*Grams.*	*Grams.*
Breakfast	150	175	75	150
10.15 a. m	200	100	75	200
Dinner	200	175	75	200
4 p. m	200	100	75	200
Supper	150	175	75	150
9 p. m	200	100	72	200
10.20 p. m	150	75	....	150
Total	1,250	[a]900	447	1,250

[a]Contained 803 grams water, 25 grams sugar, and 72 grams alcohol.

Daily routine.—The general routine of the series of experiments is indicated in the following schedule:

Daily programme—Metabolism experiments Nos. 29–31.

6.50 a. m	Take pulse and temperature.	4 p. m	Stop work. Drink 200 grams water.
7 a. m	Pass urine, weigh self dressed, collect drip and weigh absorbers.	4.15 p. m	Begin work.
		6.15 p. m	Stop work. Change underclothing.
7.30 a. m	Breakfast. Drink 150 grams water.	6.20 p. m	Supper. Drink 150 grams water.
8.15 a. m	Begin work.	6.50 p. m	Take pulse and temperature.
10.15 a. m	Stop work. Drink 200 grams water.	7 p. m	Pass urine, weigh self dressed, collect drip and weigh absorbers.
10.30 a. m	Begin work.		
12.30 p. m	Stop work.	9 p. m	Drink 200 grams water.
12.50 p. m	Take pulse and temperature.	10 p. m	Take pulse and temperature.
1 p. m	Pass urine, collect drip and weigh absorbers.	10.10 p. m	Arrange bed.
		10.20 p. m	Drink 150 grams water.
1.25 p. m	Dinner. Drink 200 grams water.	10.30 p. m	Retire.
2 p. m	Begin work.	1 a. m	Pass urine.

Table LXXV summarizes the more important statistics in the diary kept by the subject. The pulse rate was observed during periods of both work and rest. The observations of body temperature could not be made as frequently as in the previous series of (rest) experiments, but were frequent enough to afford basis of comparison between the different experiments of this series.

Amount of work done.—The total number of miles registered by the cyclometer on different days of the series of experiments and the heat equivalent of the work done each day are shown in Table LXXVI. As has already been pointed out, the amount of work done could hardly have been as large as would be required to propel a bicycle the number of miles recorded by the cyclometer. It will be observed that there was but little difference in the average amounts of work done in different days in the different experiments of this series.

TABLE LXXV.—*Summary of the diary—Metabolism experiments Nos. 29–31.*

Date and time.	Weight.	Pulse rate per minute.	Temperature.
Experiment No. 29.	*Kilograms.*		°*F.*
Mar. 16, 7 a. m	63.85	71	97.6
9 a. m		90	
10 a. m		85	
11 a. m		87	
12 m		90	
1 p. m		79	98.5
3 p. m		101	
4 p. m		108	
5 p. m		102	
6 p. m		88	
7 p. m	64.78	83	
9 p. m		82	98.2
Mar. 17, 7 a. m	64.76	66	97.4
9 a. m		92	
10 a. m		96	
11 a. m		94	
12 m		94	
1 p. m		74	98.4
3 p. m		93	
4 p. m		98	
5 p. m		93	
6 p. m		94	
7 p. m	65.12	77	97.9
8.08 p. m		76	
8.12 p. m			97.6
9 p. m		75	97.4
10 p. m		69	
10.10 p. m			96.9
Mar. 18, 7 a. m	64.76	65	97.3
9 a. m		88	
10 a. m		93	
11 a. m		91	
12 m		92	
1 p. m		69	98.0
3 p. m		91	
4 p. m		95	
5 p. m		95	
6 p. m		93	
7 p. m	64.96	79	97.8
8.15 p. m		74	
8.23 p. m			97.4
9.15 p. m		77	97.2
10.20 p. m		66	
10.25 p. m			96.4
Experiment No. 30.			
Mar. 19, 6.55 a. m	64.59	66	
7 a. m			97.6
9 a. m		97	
10.35 a. m		91	
11 a. m		89	
1 p. m		69	98.2
3 p. m		88	
4 p. m		87	
5 p. m		93	
6 p. m		93	
7 p. m	65.05	78	97.7
8 p. m		74	98.0
9 p. m		75	97.4
10.10 p. m		72	97.3
Mar. 20, 6.55 a. m	64.48	66	
7 a. m			97.8
9 a. m		101	
10 a. m		91	
11 a. m		87	
12 m		85	
12.55 p. m		68	
1 p. m			97.4
3 p. m		95	
4 p. m		92	
5 p. m		92	
6 p. m		85	
Experiment No. 30—C't'd.	*Kilograms.*		°*F.*
Mar. 20, 7 p. m	64.80	72	97.3
8 p. m		77	
8.09 p. m			
9 p. m		74	
9.07 p. m			97.2
10.10 p. m		73	96.8
Mar. 21, 6.55 a. m		64	
7 a. m	64.34		97.7
9 a. m		99	
10 a. m		93	
11 a. m		88	
12 m		84	
1 p. m		70	98.1
3 p. m		101	
4 p. m		102	
5 p. m		95	
6 p. m		89	
6.55 p. m	64.60	76	97.8
8 p. m		80	97.5
9 p. m		69	97.0
10.15 p. m		74	97.0
Experiment No. 31.			
Mar. 22, 6.55 a. m	64.09	65	
7 a. m			97.6
9 a. m		93	
10 a. m		87	
11 a. m		90	
12 m		87	
1 p. m		67	97.8
3 p. m		99	
4 p. m		93	
5 p. m		97	
6 p. m		93	
6.55 p. m		71	
7 p. m	64.55		
8 p. m		76	97.5
9 p. m		70	97.0
10.12 p. m		67	96.5
Mar. 23, 6.55 a. m		68	97.6
7 a. m	64.24		
9 a. m		100	
10 a. m		92	
11 a. m		89	
12 m		89	
1 p. m			
3 p. m		97	
4 p. m		94	
5 p. m		89	
6 p. m		90	
7 p. m	64.68	74	97.6
8 p. m		75	97.5
9 p. m		68	
10.10 p. m		66	
Mar. 24, 6.55 p. m	64.38	65	
9 a. m		89	
10 a. m		95	
11 a. m		86	
12 m		88	
12.55 p. m		68	
1 p. m			97.8
3 p. m		98	
4 p. m		98	
5 p. m		91	
6 p. m		90	
7 p. m	64.90	76	97.4
8 p. m		73	97.3
9 p. m		71	
9.04 p. m			96.9
10.05 p. m		66	
10.10 p. m			96.7
Mar. 25, 6.55 a. m	64.49	68	97.9

TABLE LXXVI.—*Record of work done—Metabolism experiments Nos. 29–31.*

Date and time.	Cyclometer reading.	Number of miles.	Actual duration of work.	Rate.	Heat equivalent.
1900.					
Experiment No. 29.			*Minutes.*	*Watts.*	*Calories.*
Mar. 16, 8.15 a. m	666.0				
10.15 a. m	687.5	21.5	120	42.0	72
12.30 p. m	708.4	20.9	120	39.7	68
4 p. m	729.8	21.4	120	39.5	68
6.15 p. m	751.1	21.3	116	37.7	62
Total		85.1	476		270
Mar. 17, 10.15 a. m	772.3	21.2	116	35.5	59
12.30 p. m	795.9	23.6	120	37.0	63
4 p. m	813.1	17.2	83	42.4	50
6.15 p. m	837.9	24.8	120	39.0	67
Total		86.8	439		239
Mar. 18, 10.15 a. m	861.8	23.9	120	36.5	62
12.30 p. m	885.0	23.2	120	35.7	61
4 p. m	906.9	21.9	120	37.4	64
6.15 p. m	930.4	23.5	120	40.0	69
Total		92.5	480		256
Experiment No. 30.					
Mar. 19, 10.15 a. m	947.9	17.5	96	40.5	55
12.30 p. m	969.2	21.3	128	35.5	65
4 p. m	986.8	17.6	120	34.0	58
6.15 p. m	1,006.7	19.9	120	37.2	65
Total		76.3	464		243
Mar. 20, 10.15 a. m	1,026.8	20.1	120	35.7	61
12.30 p. m	1,047.8	21.0	120	36.9	63
4 p. m	1,068.3	20.5	120	36.2	62
6.15 p. m	1,088.3	20.0	120	38.2	66
Total		81.6	480		252
Mar. 21, 10.15 a. m	1,109.6	21.3	120	37.4	64
12.30 p. m	1,131.4	21.8	120	36.2	62
4 p. m	1,152.8	21.4	120	37.0	63
6.15 p. m	1,173.2	20.4	120	36.5	63
Total		84.9	480		252
Experiment No. 31.					
Mar. 22, 10.15 a. m	1,194.4	21.2	120	37.4	64
12.30 p. m	1,218.0	23.6	120	38.7	66
4 p. m	1,240.9	22.9	120	39.0	67
6.15 p. m	1,262.9	22.0	120	37.0	63
Total		89.7	480		260
Mar. 23, 10.15 a. m	1,289.7	26.8	120	37.2	64
12.30 p. m	1,306.8	17.1	120	37.0	63
4 p. m	1,329.9	23.1	120	37.4	64
6.15 p. m	1,351.4	21.5	120	34.4	59
Total		88.5	480		250
Mar. 24, 10.15 a. m	1,375.8	24.4	120	37.0	63
12.30 p. m	1,400.7	24.9	120	35.7	61
4 p. m	1,423.7	23.0	104	35.7	53
6.15 p. m	1,447.4	23.7	120	34.9	60
Total		96.0	464		237

Detailed statistics of income and outgo.—The quantities of nutrients in the basal ration which was the same except for the slight differences in the composition of the milk already mentioned, and the quantities in the supplemental rations in the different experiments of this series, are shown in Table LXXVII. The outgo of matter and energy in the feces during the successive experiments of this series is shown in Table LXXVIII.

TABLE LXXVII.—*Weight, composition, and heat of combustion of foods—Metabolism experiments Nos. 29–31.*

Laboratory No.	Food material.	Weight per day.	Water.	Protein.	Fat.	Carbohydrates.	Nitrogen.	Carbon.	Hydrogen.	Heat of combustion.
	Basal ration.	*Grams.*	*Grams.*	*Grams.*	*Grams.*	*Grams.*	*Grams.*	*Grams.*	*Grams.*	*Calories.*
3186	Beef	58	35.0	20.7	1.7	....	3.32	12.12	1.73	135
3187	Butter	47	4.3	.6	40.6	....	.09	30.60	4.91	378
3192	Bread	300	109.5	28.2	6.0	152.4	4.50	87.42	12.90	879
3181	Ginger snaps	75	3.1	4.7	6.2	59.9	.75	33.24	4.96	333
3193	Parched cereal	75	3.1	9.0	1.1	60.4	1.44	32.04	4.72	315
	Sugar	25	....	....	....	25.0	....	10.52	1.62	99
		580	155.0	63.2	55.6	297.7	10.10	205.94	30.84	2,139
	EXPERIMENT No. 29.									
3189	Milk, whole	900	760.5	36.9	50.4	45.0	5.94	73.80	11.34	841
	Total basal ration	1,480	915.5	100.1	106.0	342.7	16.04	279.74	42.18	2,980
	Supplemental ration.									
	Loaf sugar	128	....	....	....	128.0	....	53.89	8.29	507
	Total ration, 1 day	**1,608**	**915.5**	**100.1**	**106.0**	**470.7**	**16.04**	**333.63**	**50.47**	**3,487**
	EXPERIMENT No. 30.									
3190	Milk, whole	900	765.0	36.0	48.6	43.2	5.76	72.00	10.80	810
	Total basal ration	1,480	920.0	99.2	104.2	340.9	15.86	277.94	41.64	2,949
	Supplemental ration.									
	Alcohol	72	....	....	....	....	....	37.56	9.39	509
	Total ration, 1 day	**1,552**	**920.0**	**99.2**	**104.2**	**340.9**	**15.86**	**315.50**	**51.03**	**3,458**
	EXPERIMENT No. 31.									
3191	Milk, whole	900	760.5	36.9	50.4	45.0	5.85	74.25	11.34	845
	Total basal ration	1,480	915.5	100.1	106.0	342.7	15.95	280.19	42.18	2,984
	Supplemental ration.									
3187	Butter	63.5	5.8	.8	54.8	....	.13	41.34	6.63	511
	Total ration, 1 day	**1,543.5**	**921.3**	**100.9**	**160.8**	**342.7**	**16.08**	**321.53**	**48.81**	**3,495**

TABLE LXXVIII.—*Weight, composition, and heat of combustion of feces—Metabolism experiment No. 29–31.*

Laboratory No.		Weight.	Water.	Protein.	Fat.	Carbohydrates.	Nitrogen.	Carbon.	Hydrogen.	Heat of combustion.
	Experiment No. 29.	*Grams.*	*Grams.*	*Grams.*	*Grams.*	*Grams.*	*Grams.*	*Grams.*	*Grams.*	*Calories.*
3195	Feces for 3 days	177.0	123.7	15.9	9.0	18.2	2.55	25.01	3.6	279
	Average per day	59.0	41.2	5.3	3.0	6.1	.85	8.34	1.2	93
	Experiment No. 30.									
3196	Feces for 3 days	142.7	101.6	12.7	6.4	14.0	2.04	19.31	2.7	212
	Average per day	47.6	33.9	4.3	2.1	4.7	.68	6.44	.9	71
	Experiment No. 31.									
	Feces for 3 days	160.1	108.1	15.2	8.2	18.1	2.43	24.32	3.4	272
	Average per day	53.4	36.0	5.1	2.7	6.0	.81	8.11	1.1	91

The amount and composition of the urine in this experiment is shown in Tables LXXIX and LXXX. The statistics are shown for 6-hour periods in experiment No. 30, in which alcohol formed a part of the diet, and for day periods in experiments Nos. 29 and and 31 without alcohol. The heat of combustion of the urine was determined in the composite sample for each day, but the carbon and hydrogen were determined only in a composite for the total 9 days of this series of experiments.

TABLE LXXIX.—*Amount, specific gravity, and nitrogen of urine by 6-hour periods—Metabolism experiments Nos. 29–31.*

Date.	Period.	Amount.	Specific gravity.	Nitrogen.	
	Experiment No. 29.				
1900.		*Grams.*		*Per cent.*	*Grams.*
Mar. 16–17	7 a. m. to 7 a. m	694.9	1.034	2.19	15.24
17–18	7 a. m. to 7 a. m	777.2	1.031	2.07	16.11
18–19	7 a. m. to 7 a. m	890.8	1.030	1.79	15.97
	Total				47.32
	Experiment No. 30.				
19	7 a. m to 7 p. m	247.0	1.029	1.71	4.22
19	1 p. m. to 7 p. m	358.3	1.026	1.35	4.84
19–20	7 p. m. to 1 a. m	196.8	1.031	2.02	3.98
20	1 a. m. to 7 a. m	165.2	1.031	2.18	3.60
	Total	967.3			16.64
	Total by composite	967.3	1.029	1.74	16.83
20	7 a. m. to 1 p. m	309.5	1.027	1.47	4.55
20	1 p. m. to 7 p. m	320.7	1.027	1.55	4.97
20–21	7 p. m. to 1 a. m	254.6	1.025	1.80	4.58
21	1 a. m. to 7 a. m	171.9	1.029	2.15	3.70
	Total	1,056.7			17.80
	Total by composite	1,056.7	1.027	1.69	17.86
21	7 a. m. to 1 p. m	355.3	1.021	1.28	4.55
21	1 p. m. to 7 p. m	409.5	1.020	1.18	4.83
21–22	7 p. m. to 1 a. m	217.5	1.026	1.89	4.11
22	1 a. m. to 7 a. m	154.2	1.028	2.19	3.38
	Total	1,136.5			16.87
	Total by composite	1,136.5	1.023	1.47	16.70
	Experiment No. 31.				
22–23	7 a. m. to 7 a. m	812.3	1.030	1.98	16.05
23–24	7 a. m. to 7 a. m	790.5	1.030	1.93	15.24
24–25	7 a. m. to 7 a. m	880.0	1.030	1.71	15.02
	Total				46.31

TABLE LXXX.—*Daily elimination of carbon, hydrogen, and water in urine—Metabolism experiments Nos. 29–31.*

Date.	Amount.	Carbon.		Hydrogen.		Water.		Heat of combustion.	
								Per gram.	Total.
1900.	*Grams.*	*Per cent.*	*Grams.*	*Per cent.*	*Grams.*	*Per cent.*	*Grams.*	*Calories.*	*Calories.*
Mar. 16–17	694.9	....	10.78	....	2.86	....	641.0	0.193	134
17–18	777.2	....	11.39	....	3.03	....	720.3	.173	134
18–19	890.8	....	11.29	....	3.00	....	834.3	.150	134
Total	2,362.9	....	33.46	....	8.89	....	2,195.6	....	402
19–20	967.3	....	11.76	....	3.13	....	908.5	.141	136
20–21	1,056.7	....	12.59	....	3.34	....	993.8	.134	142
21–22	1,136.5	....	11.93	....	3.17	....	1,076.8	.125	142
Total	3,160.5	....	36.28	....	9.64	....	2,979.1	....	420
22–23	812.3	....	11.35	....	3.01	....	755.6	.162	132
23–24	790.5	....	10.78	....	2.86	....	736.6	.163	129
24–25	880.0	....	10.62	....	2.82	....	826.9	.145	128
Total	2,482.8	....	32.75	....	8.69	....	2,319.1	....	389
Total 9 days	8,006.2	1.28	102.49	0.34	27.22	....	7,493 8	....	1,211

The quantities of carbon dioxid and water in the ventilating air current are given in Tables LXXXI to LXXXIII. These statistics are given in detail for experiment No. 30 in which alcohol was used, and summarized for the other two experiments of the series.

TABLE LXXXI.—*Comparison of residual amounts of carbon dioxid and water in the chamber at the beginning and end of each period, and the corresponding gain or loss—Metabolism experiment No. 30.*

Date.		End of period.	Carbon dioxid.		Water.				
			Total amount in chamber.	Gain (+) or loss (−) over preceding period.	Total amount of vapor remaining in chamber.	Gain (+) or loss (−) over preceding period.	Change in weight of absorbers. Gain (+) or loss (−).	Drip [a] from absorbers.	Total amount gained (+) or lost (−) during the period.
1900.			*Grams.*	*Grams.*	*Grams.*	*Grams.*	*Grams.*	*Grams.*	*Grams.*
Mar.	19	7 a. m	26.8	....	48.1	....	....	([b])	....
	19	1 p. m	79.6	+52.8	53.4	+5.3	+152	140.0	+297.3
	19	7 p. m	84.4	+ 4.8	57.2	+3.8	+ 11	367.4	+382.2
	20	1 a. m	23.9	−60.5	52.6	−4.6	− 77	32.4	− 49.2
	20	7 a. m	31.9	+ 8.0	48.8	−3.8	− 77	24.3	− 56.5
		Total	....	+ 5.1	....	+ .7	+ 9	564.1	+573.8
	20	1 p. m	76.6	+44.7	55.9	+7.1	+162	170.0	+339.1
	20	7 p. m	63.5	−13.1	51.3	−4.6	− 26	365.1	+334.5
	21	1 a. m	27.2	−36.3	51.5	+ .2	− 78	23.1	− 54.7
	21	7 a. m	25.7	− 1.5	47.3	−4.2	− 79	17.0	− 66.2
		Total	....	− 6.2	....	−1.5	− 21	575.2	+552.7
	21	1 p. m	71.8	+46.1	53.2	+5.9	+188	155.0	+348.9
	21	7 p. m	70.7	− 1.1	52.3	− .9	+ 10	359.4	+368.5
	22	1 a. m	25.7	−45.0	47.1	−5.2	−101	34.4	− 71.8
	22	7 a. m	26.4	+ .7	45.2	−1.9	−102	22.0	− 81.9
		Total	....	+ .7	....	−2.1	− 5	570.8	+563.7

[a] Including also the perspiration in underclothes.

[b] The drip was collected and weighed but once a day. The volume was roughly observed at 1 p. m., 7 p. m. and 7 a. m., and this volume taken as a rough approximation to the actual weight of drip for the different periods The small amount of drip observed at 7 a. m. was divided equally between the two night periods.

TABLE LXXXII.—*Record of carbon dioxid in ventilating air current—Metabolism experiments Nos. 29–31.*

Date.	Period.	(a) Ventilation. Number of liters of air.	Carbon dioxid. In incoming air. (b) Per liter.	(c) Total, $a \cdot b$.	(d) In outgoing air.	(e) Total excess in outgoing air, $d - c$.	(f) Correction for amount remaining in chamber.	(g) Corrected amount exhaled by subject, $e + f$.	(h) Total weight of carbon exhaled, $g \times \frac{3}{11}$.
1900.	*Experiment No. 29.*	*Liters.*	*Mg.*	*Grams.*	*Grams.*	*Grams.*	*Grams.*	*Grams.*	*Grams.*
Mar. 16–17	7 a. m. to 7 a. m.	110, 386	....	65. 2	1, 306. 7	1, 241. 5	+ 0. 2	1, 241. 7	338. 7
17–18	7 a. m. to 7 a. m.	110, 385	....	65. 5	1, 252. 7	1, 187. 2	− 1. 9	1, 185. 3	323. 3
18–19	7 a. m. to 7 a. m.	108, 831	....	61. 4	1, 315. 2	1, 253. 8	+ 3. 0	1, 256. 8	342. 7
	Experiment No. 30.								
19	7 a. m. to 7 a. m.	25, 653	0. 575	14. 7	389. 2	374. 4	+52. 8	427. 2	116. 5
19	1 p. m. to 7 p. m.	25, 653	. 587	15. 1	442. 2	427. 2	+ 4. 8	432. 0	117. 8
19–20	7 p. m. to 1 a. m.	27, 208	. 577	15. 7	254. 6	238. 9	−60. 5	178. 4	48. 7
20	1 a. m. to 7 a. m.	27, 208	. 573	15. 6	151. 6	136. 0	+ 8. 0	144. 0	39. 3
	Total	105, 722	....	61. 1	1, 237. 6	1, 176. 5	+ 5. 1	1, 181. 6	322. 3
20	7 a. m. to 1 p. m.	25, 653	. 576	14. 8	377. 0	362. 2	+44. 7	406. 9	111. 0
20	1 p. m. to 7 p. m.	27, 208	. 582	15. 8	439. 5	423. 7	−13. 1	410. 6	112. 0
20–21	7 p. m. to 1 a. m.	27, 208	. 563	15. 3	247. 9	232. 6	−36. 3	196. 3	53. 5
21	1 a. m. to 7 a. m.	27, 208	. 578	15. 7	149. 6	133. 9	− 1. 5	132. 4	36. 1
	Total	107, 277	....	61. 6	1, 214. 0	1, 152. 4	− 6. 2	1, 146. 2	312. 6
21	7 a. m. to 1 p. m.	26, 430	. 587	15. 5	389. 2	373. 7	+46. 1	419. 8	114. 5
21	1 p. m. to 7 p. m.	26, 430	. 581	15. 3	445. 5	430. 2	− 1. 1	429. 1	117. 0
21–22	7 p. m. to 1 a. m.	27, 985	. 569	15. 9	232. 5	216. 6	−45. 0	171. 6	46. 8
22	1 a. m. to 7 a. m.	27, 985	. 575	16. 1	148. 6	132. 5	+ 0. 7	133. 2	36. 3
	Total	108, 830	....	62. 8	1, 215. 8	1, 153. 0	+ 0. 7	1, 153. 7	314. 6
	Experiment No. 31.								
22–23	7 a. m. to 7 a. m.	106, 497	....	61. 7	1, 210. 2	1, 148. 5	− 0. 7	1, 147. 8	313. 1
23–24	7 a. m. to 7 a. m.	108, 051	....	61. 8	1, 223. 6	1, 161. 8	− 1. 0	1, 160. 8	316. 6
24–25	7 a. m. to 7 a. m.	108, 830	....	62. 3	1, 224. 5	1, 162. 2	+ 2. 9	1, 165. 1	317. 8

TABLE LXXXIII.—*Record of water in ventilating air current—Metabolism experiments Nos. 29–31.*

Date.	Period.	(a) Ventilation. Number of liters of air.	Water in incoming air. (b) Per liter.	(c) Total, $a \cdot b$.	Water in outgoing air. (d) Amount condensed in freezers.	(e) Amount not condensed in freezers.	(f) Total, $d + e$.	(g) Total excess water in outgoing air, $f - c$.	(h) Correction for water remaining in chamber.	(i) Total water of respiration and perspiration, $g + h$.
1900.	*Experiment No. 29.*	*Liters.*	*Mg.*	*Grams.*	*Grams.*	*Grams.*	*Grams.*	*Grams.*	*Grams.*	*Grams.*
Mar. 16–17	7 a. m. to 7 a. m.	110, 386	....	89. 8	1, 025. 5	176. 7	1, 202. 2	1, 112. 4	+555. 1	1, 667. 5
17–18	7 a. m. to 7 a. m.	110, 385	....	91. 1	992. 5	179. 4	1, 171. 9	1, 080. 8	+358. 6	1, 439. 4
18–19	7 a. m. to 7 a. m.	108, 831	....	92. 8	1, 033. 9	175. 6	1, 209. 5	1, 116. 7	+619. 8	1, 736. 5
	Experiment No. 30.									
19	7 a. m. to 1 p. m.	25, 653	0. 970	24. 9	239. 5	44. 3	283. 8	258. 9	+297. 3	556. 2
19	1 p. m. to 7 p. m.	25, 653	. 969	24. 9	257. 1	40. 1	297. 2	272. 3	+382. 2	654. 5
19–20	7 p. m. to 1 a. m.	27, 208	. 939	25. 6	256. 5	45. 5	302. 0	276. 4	− 49. 2	227. 2
20	1 a. m. to 7 a. m.	27, 208	. 875	23. 8	253. 7	38. 7	292. 4	268. 6	− 56. 5	212. 1
	Total	105, 722	....	99. 2	1, 006. 8	168. 6	1, 175. 4	1, 076. 2	+573. 8	1, 650. 0
20	7 a. m. to 1 p. m.	25, 653	. 977	25. 1	250. 6	41. 8	292. 4	267. 3	+339. 1	606. 4
20	1 p. m. to 7 p. m.	27, 208	. 892	24. 3	270. 5	42. 6	313. 1	288. 8	+334. 5	623. 3
20–21	7 p. m. to 1 a. m.	27, 208	. 814	22. 1	256. 1	45. 2	301. 3	279. 2	54. 7	224. 5
21	1 a. m. to 7 a. m.	27, 208	. 781	21. 2	261. 8	37. 7	299. 5	278. 3	66. 2	212. 1
	Total	107, 277	....	92. 7	1, 039. 0	167. 3	1, 206. 3	1, 113. 6	+552. 7	1, 666. 3

TABLE LXXXIII.—*Record of water in ventilating air current—Metabolism experiments Nos. 29–31*—Continued.

Date.	Period.	(a) Ventilation. Number of liters of air.	Water in incoming air. (b) Per liter.	(c) Total, $a \times b$.	Water in outgoing air. (d) Amount condensed in freezers.	(e) Amount not condensed in freezers.	(f) Total, $d+e$.	(g) Total excess water in outgoing air, $f-c$.	(h) Correction for water remaining in chamber.	(i) Total water of respiration and perspiration, $g+h$.
	Experiment No. 29—Continued.									
1900.		*Liters.*	*Mg.*	*Grams.*	*Grams.*	*Grams.*	*Grams.*	*Grams.*	*Grams.*	*Grams.*
Mar. 21	7 a. m. to 1 p. m..	26,430	.828	21.9	250.4	39.8	290.2	268.3	+348.9	617.2
21	1 p. m. to 7 p. m..	26,430	.816	21.6	268.1	38.8	306.9	285.3	+368.5	653.8
21–22	7 p. m. to 1 a. m..	27,985	.782	21.9	253.3	43.3	296.6	274.7	− 71.8	202.9
22	1 a. m. to 7 a. m..	27,985	.767	21.5	249.9	37.4	287.3	265.8	− 81.9	183.9
	Total	108,830	......	86.9	1,021.7	159.3	1,181.0	1,094.1	+563.7	1,657.8
	Experiment No. 31.									
22–23	7 a. m. to 7 a. m..	106,497	......	87.2	994.4	156.4	1,150.8	1,063.6	+573.8	1,637.4
23–24	7 a. m. to 7 a. m..	108,051	......	90.3	999.0	160.3	1,159.3	1,069.0	+521.1	1,590.1
24–25	7 a. m. to 7 a. m..	108,830	......	88.7	1,015.0	162.6	1,177.6	1,088.9	+566.0	1,654.9

Table LXXXIV summarizes the calorimetric measurements in experiments Nos. 29 and 31, and gives the details of these measurements in 6-hour periods during experiment No. 30.

TABLE LXXXIV.—*Summary of calorimetric measurements—Metabolism experiments Nos. 29–31.*

Date.	Period.	(a) Heat measured in terms of C_{20}.	(b) Change of temperature of calorimeter.	(c) Capacity correction of calorimeter, $b \times 60$.	(d) Correction due to temperature of food and dishes.	(e) Water vaporized equals total amount exhaled less amount condensed in chamber.	(f) Heat used in vaporization of water, $e \times 0.592$.	(g) Total heat determined, $a+c+d+f$
	Experiment No. 29.							
1900.		*Calories.*	*Degrees.*	*Calories.*	*Calories.*	*Grams.*	*Calories.*	*Calories.*
Mar. 16–17	7 a. m. to 7 a. m	2,997.4	+0.13	+ 7.80	+5.43	1,112.8	658.7	3,669.3
17–18	7 a. m. to 7 a. m	2,783.0	+ .09	+ 5.40	+3.52	1,078.4	638.4	3,430.3
18–19	7 a. m. to 7 a. m	2,988.5	+ .20	+12.00	+6.00	1,120.1	663.0	3,669.5
	Experiment No. 30.							
19	7 a. m. to 1 p. m........	1,060.4	+ .03	+ 1.80	+9.40	264.2	156.4	1,228.0
19	1 p. m. to 7 p. m........	1,114.7	+ .01	+ .60	−2.23	276.1	163.4	1,276.5
19–20	7 p. m. to 1 a. m........	449.3	+ .01	+ .60	+1.53	271.8	160.9	612.3
20	1 a. m. to 7 a. m	241.6	+ .02	+ 1.20	....	264.8	156.8	399.6
	Total............	2,866.0	+ .07	+ 4.20	+8.70	1,076.9	637.5	3,516.4
20	7 a. m. to 1 p. m........	1,029.1	+ .02	+ 1.20	+6.35	274.4	162.4	1,199.0
20	1 p. m. to 7 p. m........	1,089.0	+ .01	+ .60	+ .81	284.2	168.2	1,258.6
20–21	7 p. m. to 1 a. m........	410.0	+ .01	+ .60	+ .70	279.4	165.4	576.7
21	1 a. m. to 7 a. m	245.7	+ .02	+ 1.20	....	274.1	162.3	409.2
	Total............	2,773.8	+ .06	+ 3.60	+7.86	1,112.1	658.3	3,443.5
21	7 a. m. to 1 p. m........	1,067.1	− .01	− .60	+7.81	274.2	162.3	1,236.6
21	1 p. m. to 7 p. m........	1,094.9	+ .01	+ .60	−8.17	284.4	168.4	1,255.8
21–22	7 p. m. to 1 a. m........	403.8	+ .01	+ .60	+2.44	269.5	159.5	566.3
21	1 a. m. to 7 a. m........	236.6	+ .01	+ .60	....	263.9	156.2	393.4
	Total............	2,802.4	+ .02	+ 1.20	+2.08	1,092.0	646.4	3,452.1
	Experiment No. 31.							
22–23	7 a. m. to 7 a. m	2,797.6	....	....	+2.07	1,063.6	629.6	3,429.3
23–24	7 a. m. to 7 a. m	2,780.9	+ .04	+ 2.40	−3.33	1,069.0	632.8	3,412.8
24–25	7 a. m. to 7 a. m	2,762.2	+ .01	+ .60	+8.30	1,091.6	646.1	3,417.2

The alcohol, or reducing material equivalent to alcohol, was determined in the urine and freezer water of each day of experiment No. 30, and on the 3 days of the preceding and following experiments, Nos. 29 and 31, respectively. The amount of reducing material in the air current on each day of the 9 days of this series of experiments was also determined. Table LXXXV summarizes these determinations. The determinations of the reducing material in the urine on the first day of experiment No. 29 was lost, so that we can only estimate the total reducing material on that day. It was, however, probably not far different from the second and third days of this experiment. The average elimination of reducing material per day from all sources in experiments Nos. 29 and 31 amounted to the equivalent of 0.32 gram of alcohol. In the third from the last column of Table LXXXV is given the total outgo of alcohol in experiment No. 30, which amounts to 0.76 gram per day. This value is obtained by subtracting from the 1.09 grams of total alcohol and reducing material equivalent to alcohol the 0.33 gram of reducing material determined during the experiments in which alcohol did not form a part of the diet. The total alcohol metabolized in the body was 98.9 per cent of that ingested.

TABLE LXXXV.—*Alcohol ingested and excreted—Metabolism experiment Nos. 29–31.*

Date.	Alcohol ingested.	Alcohol excreted, including other reducing material calculated as alcohol.					Alcohol excreted, unoxidized.[a]	Alcohol metabolized in body.	
		In urine (distillate).	In drip (distillate).	In freezer water (distillate).	In air current.	Total.			
1900.									
Experiment No. 29.	*Grams.*	*Grams.*	*Grams.*	*Grams.*	*Grams.*	*Grams.*	*Grams.*	*Grams.*	*Per cent.*
Mar. 16–17	....	([b])		Trace.	0.35	....	....	....	....
17–18	....	0.02	0.01	0.01	.33	0.36	....	....	....
18–19	....	.02		Trace.	.35	.37	....	....	....
Experiment No. 30.									
Mar. 19–20	72.0	.05		0.02	.95	1.06	0.73	71.3	99.0
20–21	72.0	.06	.12	.01	1.00	1.11	.78	71.2	98.9
21–22	72.0	.06		.01	1.00	1.11	.78	71.2	98.9
Total	216.0	.17	.12	.04	2.95	3.28	2.29	213.7	....
Average per day	72.0	.06	.04	.01	.98	1.09	.76	71.2	98.9
Experiment No. 31.									
Mar. 22–23	....	.02		.01	.30	.33	....	....	....
23–24	....	.01	.01	Trace.	.28	.30	....	....	....
24–25	....	.02		Trace.	.26	.28	....	....	....

[a] Equals total reducing material excreted less 0.33 gram of reducing material not alcohol, the average for the days on which no alcohol was consumed.
[b] Not determined.

Balance of income and outgo of matter and energy.—The income and outgo of nitrogen, carbon, hydrogen, and energy in the different experiments of this series are shown in Tables LXXXVI to LXXXIX.

TABLE LXXXVI.—*Income and outgo of nitrogen and carbon—Metabolism experiments Nos. 29–31.*

Date and period.	Nitrogen.				Carbon.					
	(*a*) In food.	(*b*) In feces.	(*c*) In urine.[a]	(*d*) Gain (+) or loss (−), $a-(b+c)$.	(*e*) In food.	(*f*) In feces.	(*g*) In urine.	(*h*) In respiratory products.	(*i*) In alcohol eliminated.	(*k*) Gain (+) or loss (−), $e-(f+g+h+i)$.
1900.										
Experiment No. 29.	*Grams.*	*Grams.*	*Grams.*	*Grams.*	*Grams.*	*Grams.*	*Grams.*	*Grams.*	*Grams.*	*Grams.*
Mar. 16–17, 7 a. m. to 7 a. m.	16.0	0.9	15.4	−0.3	333.6	8.3	10.8	338.7	....	−24.2
17–18, 7 a. m. to 7 a. m.	16.1	.8	16.3	−1.0	333.7	8.4	11.4	323.3	....	− 9.4
18–19, 7 a. m. to 7 a. m.	16.0	.9	16.2	−1.1	333.6	8.3	11.3	342.7	....	−28.7
Total	48.1	2.6	47.9	−2.4	1,000.9	25.0	33.5	1,004.7	....	−62.3
Average 1 day......	16.0	.8	16.0	− .8	333.6	8.3	11.2	334.9	....	−20.8
Experiment No. 30.										
Mar. 19–20, 7 a. m. to 7 a. m.	15.9	.7	16.8	−1.6	315.5	6.4	11.8	322.3	.4	−25.4
20–21, 7 a. m. to 7 a. m.	15.8	.6	18.0	−2.8	315.5	6.5	12.6	312.6	.4	−16.6
21–22, 7 a. m. to 7 a. m.	15.9	.7	17.1	−1.9	315.5	6.4	11.9	314.6	.4	−17.8
Total	47.6	2.0	51.9	−6.3	946.5	19.3	36.3	949.5	1.2	−59.8
Average 1 day......	15.9	.7	17.3	−2.1	315.5	6.4	12.1	316.5	.4	−19.9
Experiment No. 31.										
Mar. 22–23, 7 a. m. to 7 a. m.	16.1	.8	16.3	−1.0	321.5	8.1	11.3	313.1	....	−11.0
23–24, 7 a. m. to 7 a. m.	16.0	.8	15.4	− .2	321.6	8.1	10.8	316.6	....	−13.9
24–25, 7 a. m. to 7 a. m.	16.1	.8	15.2	+ .1	321.5	8.1	10.6	317.8	....	−15.0
Total	48.2	2.4	46.9	−1.1	964.6	24.3	32.7	947.5	....	−39.9
Average 1 day......	16.1	.8	15.6	− .3	321.5	8.1	10.9	315.8	....	−13.3

[a] Nitrogen in perspiration, 0.2 gram per day, is included in this column.

TABLE LXXXVII.—*Income and outgo of water and hydrogen—Metabolism experiments Nos. 29–31.*

Date and period.	Water.						Hydrogen.						
	(*a*) In food.	(*b*) In drink.	(*c*) In feces.	(*d*) In urine.	(*e*) In respiratory products.	(*f*) Apparent loss, $a+b-(c+d+e)$.	(*g*) In food.	(*h*) In feces.	(*i*) In urine.	(*k*) In alcohol eliminated.	(*l*) Apparent gain, $g-(h+i+k)$.	(*m*) Loss from water, $f\div 9$.	(*n*) Total gain (+) or loss (−), $l+m$.
1900.													
Experiment No. 29.	*Grams.*	*Grams.*	*Grams.*	*Grams.*	*Grams.*	*Grams.*	*Grams.*	*Grams.*	*Grams.*	*Grams.*	*Grams.*	*Grams.*	*Grams.*
Mar. 16–17, 7 a. m. to 7 a. m.	915.5	1,250.0	41.2	641.0	1,667.5	184.2	50.5	1.2	2.9	......	46.4	20.5	+25.9
17–18, 7 a. m. to 7 a. m.	915.5	1,250.0	41.3	720.3	1,439.4	35.5	50.5	1.2	3.0	......	46.3	3.9	+42.4
18–19, 7 a. m. to 7 a. m.	915.5	1,250.0	41.2	834.3	1,736.5	446.5	50.5	1.2	3.0	......	46.3	49.6	− 3.3
Total	2,746.5	3,750.0	123.7	2,195.6	4,843.4	666.2	151.5	3.6	8.9	......	139.0	74.0	+65.0
Average 1 day..	915.5	1,250.0	41.2	731.9	1,614.5	222.1	50.5	1.2	3.0	......	46.3	24.6	+21.7

TABLE LXXXVII.—*Income and outgo of water and hydrogen—Metabolism experiments Nos. 29–31*—Continued.

Date and period.	Water.						Hydrogen.						
	(a) In food.	(b) In drink.	(c) In feces.	(d) In urine.	(e) In respiratory products.	(f) Apparent loss $a-b-(c-d-e)$.	(g) In food.	(h) In feces.	(i) In urine.	(k) In alcohol eliminated.	(l) Apparent gain, $g-(h+i+k)$.	(m) Loss from water, $f\div 9$.	(n) Total gain (+) or loss (−), $l-m$.
1900.													
Experiment No. 30.													
	Grams.	*Grams.*	*Grams.*	*Grams.*	*Grams.*	*Grams.*	*Grams.*	*Grams.*	*Grams.*	*Grams.*	*Grams.*	*Grams.*	*Grams.*
Mar. 19–20, 7 a. m. to 7 a. m.	920.0	1,250.0	33.9	908.5	1,650.0	422.4	51.0	0.9	3.1	0.1	46.9	46.9	....
20–21, 7 a. m. to 7 a. m.	920.0	1,250.0	33.8	993.8	1,666.3	523.9	51.0	0.9	3.3	.1	46.7	58.2	−11.5
21–22, 7 a. m. to 7 a. m.	920.0	1,250.0	33.9	1,076.8	1,657.8	598.5	51.0	0.9	3.2	.1	46.8	66.5	−19.7
Total	2,760.0	3,750.0	101.6	2,979.1	4,974.1	1,544.8	153.0	2.7	9.6	.3	140.4	171.6	−31.2
Average 1 day..	920.0	1,250.0	33.9	993.0	1,658.0	514.9	51.0	0.9	3.2	.1	46.8	57.2	−10.4
Experiment No. 31.													
Mar. 22–23, 7 a. m. to 7 a. m.	921.3	1,250.0	36.0	755.6	1,637.4	257.7	48.8	1.1	3.0	......	44.7	28.6	−16.1
23–24, 7 a. m. to 7 a. m.	921.3	1,250.0	36.1	736.6	1,590.1	191.5	48.8	1.2	2.9	......	44.7	21.3	−23.4
24–25, 7 a. m. to 7 a. m.	921.3	1,250.0	36.0	826.9	1,654.9	346.5	48.8	1.1	2.8	......	44.9	38.5	− 6.4
Total	2,763.9	3,750.0	108.1	2,319.1	4,882.4	795.7	146.4	3.4	8.7	......	134.3	88.4	−45.9
Average 1 day..	921.3	1,250.0	36.0	773.0	1,627.5	265.2	48.8	1.1	2.9	......	44.8	29.5	−15.3

TABLE LXXXVIII.—*Gain or loss of protein (N×6.25), fat, and water—Metabolism experiments Nos. 29–31.*

Date and period.	(a) Nitrogen gained (+) or lost (−).	(b) Protein gained (+) or lost (−), $a\times 6.25$.	(c) Total carbon gained (+) or lost (−).	(d) Carbon in protein gained (+) or lost (−), $b\times .53$.	(e) Carbon in fat, etc., gained (+) or lost (−), $c-d$.	(f) Fat gained (+) or lost (−), $e\div .761$.	(g) Total hydrogen gained (+) or lost (−).	(h) Hydrogen in protein gained (+) or lost (−), $b\times .07$.	(i) Hydrogen in fat gained (+) or lost (−), $f\times .118$.	(k) Hydrogen in water, etc., gained (+) or lost (−), $g-(h+i)$.	(l) Water gained (+) or lost (−), $k\times 9$.
1900.											
Experiment No. 29.											
	Grams.	*Grams.*	*Grams.*	*Grams.*	*Grams.*	*Grams.*	*Grams.*	*Grams.*	*Grams.*	*Grams.*	*Grams.*
Mar. 16–17, 7 a. m. to 7 a. m..	−0.3	− 1.9	−24.2	− 1.0	−23.2	−30.5	−25.9	−0.1	−3.6	−29.6	−266.4
17–18, 7 a. m. to 7 a. m..	−1.0	− 6.2	− 9.4	− 3.3	− 6.1	− 8.0	−42.4	− .4	− .9	−43.7	−393.3
18–19, 7 a. m. to 7 a. m..	−1.1	− 6.9	−28.7	− 3.7	−25.0	−32.9	− 3.3	− .5	−3.9	− 1.1	− 9.9
Total..................	−2.4	−15.0	−62.3	− 8.0	−54.3	−71.4	−65.0	−1.0	−8.4	−74.4	−669.6
Average 1 day	− .8	− 5.0	−20.8	− 2.7	−18.1	−23.8	−21.7	− .3	−2.8	−24.8	−223.2
Experiment No. 30.											
Mar. 19–20, 7 a. m. to 7 a. m..	−1.6	−10.0	−25.4	− 5.3	−20.1	−26.4	....	− .7	−3.1	− 3.8	− 34.2
20–21, 7 a. m. to 7 a. m..	−2.8	−17.5	−16.6	− 9.3	− 7.3	− 9.6	−11.5	−1.2	−1.1	− 9.2	− 82.8
21–22, 7 a. m. to 7 a. m..	−1.9	−11.9	−17.8	− 6.3	−11.5	−15.1	−19.7	− .8	−1.8	−17.1	−153.9
Total..................	−6.3	−39.4	−59.8	−20.9	−38.9	−51.1	−31.2	−2.7	−6.0	−22.5	−202.5
Average 1 day	−2.1	−13.1	−19.9	− 6.9	−13.0	−17.0	−10.4	− .9	−2.0	− 7.5	− 67.5
Experiment No. 31.											
Mar. 22–23, 7 a. m. to 7 a. m..	−1.0	− 6.2	−11.0	− 3.3	− 7.7	−10.1	−16.1	− .4	−1.2	−17.7	−159.3
23–24, 7 a. m. to 7 a. m..	− .2	− 1.3	−13.9	− .7	−13.2	−17.3	−23.4	− .1	−2.0	−25.5	−229.5
24–25, 7 a. m. to 7 a. m..	− .1	− .6	−15.0	− .3	−15.3	−20.1	− 6.4	....	−2.4	− 8.8	− 79.2
Total..................	−1.1	− 6.9	−39.9	− 3.7	−36.2	−47.5	−45.9	− .5	−5.6	−52.0	−468.0
Average 1 day	− .3	− 2.3	−13.3	− 1.2	−12.1	−15.9	−15.3	− .1	−1.9	−17.3	−156.0

TABLE LXXXIX.—*Income and outgo of energy—Metabolism experiments Nos. 29–31.*

Date and period.	(a) Heat of combustion of food eaten.	(b) Heat of combustion of feces.	(c) Heat of combustion of urine.	(m) Heat of combustion of alcohol eliminated.	(d) Estimated heat of combustion of protein gained (+) or lost (−).	(e) Estimated heat of combustion of fat gained (+) or lost (−).	(f) Estimated energy of material oxidized in the body, $a-(b+c+m+d+e)$.	(g) Heat determined.	Heat determined greater (+) or less (−) than estimated. (h) $f-g$.	(i) $h \div f$.
1900.										
Experiment No. 29.	*Calories.*	*Calories.*	*Calories.*	*Calories.*	*Calories.*	*Calories.*	*Calories.*	*Calories.*	*Calories.*	*Calories.*
Mar. 16–17, 7 a. m. to 7 a. m.	3,487	93	134	....	− 11	− 291	3,562	3,669	+ 107	+ 3.0
17–18, 7 a. m. to 7 a. m.	3,487	93	134	....	− 35	− 76	3,371	3,430	+ 59	+ 1.7
18–19, 7 a. m. to 7 a. m.	3,487	93	134	....	− 39	− 314	3,613	3,669	+ 56	+ 1.5
Total	10,461	279	402	....	− 85	− 681	10,546	10,768	+ 222	....
Average 1 day	3,487	93	134	....	− 28	− 227	3,515	3,589	+ 74	+ 2.1
Experiment No. 30.										
Mar. 19–20, 7 a. m. to 7 a. m.	3,458	71	136	5	− 57	− 252	3,555	3,516	− 39	− 1.1
20–21, 7 a. m. to 7 a. m.	3,458	70	142	5	− 99	− 92	3,432	3,443	+ 11	+ .3
21–22, 7 a. m. to 7 a. m.	3,458	71	142	6	− 67	− 144	3,450	3,452	+ 2	+ .1
Total	10,374	212	420	16	− 223	− 488	10,437	10,411	− 26	....
Average 1 day	3,458	71	140	5	− 74	− 163	3,479	3,470	− 9	− .3
Experiment No. 31.										
Mar. 22–23, 7 a. m. to 7 a. m.	3,495	91	132	....	− 35	− 96	3,403	3,429	+ 26	+ .8
23–24, 7 a. m. to 7 a. m.	3,495	90	129	....	− 7	− 165	3,448	3,413	− 35	− 1.0
24–25, 7 a. m. to 7 a. m.	3,495	91	128	....	+ 3	− 192	3,465	3,417	− 48	− 1.4
Total	10,485	272	389	....	− 39	− 453	10,316	10,259	− 57	....
Average 1 day	3,495	91	129	....	− 13	− 151	3,439	3,420	− 19	− .6

EXPERIMENTS NOS. 32–34—WORK. NO. 33 WITH ALCOHOL DIET.

Subject.—J. F. S., the same as in experiments of the two previous series, Nos. 26–31. His weight with underclothing was about 66.5 kilograms (145½ pounds).

Occupation during experiment.—Work, 8 hours a day, upon a stationary bicycle, as in the previous series of experiments.

Duration.—This experiment was the second of a series of 3, each of which continued 3 days. A preliminary period of 4 days preceded the first. The series was intended to be as nearly as possible a repetition of the previous series, Nos. 29–31, with the exception that the order in which the supplemental materials were added to the basal ration was butter, alcohol, sugar, while in the previous series the order was sugar, butter, alcohol. The preliminary period began with breakfast April 16, 1900, and the subject entered the respiration chamber on the evening of April 19. The first experiment of the series, No. 32, began at 7 a. m. April 20; the second, No. 33, at 7 a. m. April 23, and the third, No. 34, at 7 a. m. April 26. The subject thus spent 9 days and 10 nights within the respiration chamber.

Diet.—As has already been indicated, this series was a duplicate in reverse order of the previous series. There was a basal ration differing slightly in the different experiments on account of differences in the composition of the milk. This ration furnished approximately 100 grams of protein and 2,980 calories of energy, or practically the same as in the previous series. To this basal ration were added: In No. 32, 63.5 grams of butter per day, furnishing 1 gram of protein and 509 calories of energy; in No. 33, 79.5 grams of 90.6 per cent alcohol, furnishing 72 grams of absolute alcohol and 509 calories of energy per day, and in No. 34, 128 grams of cane sugar, furnishing 507 calories of energy. The total ration therefore in this series of experiments furnished 100 grams of protein and 3,490 calories of energy per day. The alcohol was taken in 6 doses, as usual, and the sugar was also taken at frequent intervals, but the butter was consumed in about equal portions at breakfast, dinner, and supper. The total amount of water in the drink on each day of the series of experiments amounted to 1,250 grams. The kinds and quantities of food served at each meal and the quantities of drink at different periods of the day were as follows:

Diet in metabolism experiments Nos. 32–34.

FOOD—BASAL RATION.

	Breakfast.	Dinner.	Supper.	Total.
	Grams.	*Grams.*	*Grams.*	*Grams.*
Beef	....	58	....	58
Butter	9.0	17	9.0	35
Bread	75.0	150	75.0	300
Ginger snaps	25.0	25	25.0	75
Parched cereal	37.5	....	37.5	75
Sugar[a]	17.5	....	17.5	35
Milk, whole	340.0	340	340.0	1,020

[a] Eaten on parched cereal in experiments Nos. 32 and 34; mostly added to water and alcohol in experiment No. 33.

FOOD—SUPPLEMENTAL RATION.

Experiment No. 32, April 20–22.—Sixty-two grams butter added to basal ration. This amount also supplemented the ration during the preliminary period.

Experiment No. 33, April 23–25.—Seventy-two grams absolute alcohol daily. This was supplied in 79.5 grams of 90.57 per cent alcohol, which was made up to 900 grams with the addition of 25 grams sugar and the rest water.

Experiment No. 34, April 26–28.—The basal ration was increased by the addition of 128 grams of cane sugar.

DRINK.

Time.	Experiment No. 32.	Experiment No. 33.		Experiment No. 34.
	Water.	Alcohol and sweetened water.[a]	Water.	Water.
	Grams.	*cc.*	*Grams.*	*Grams.*
Breakfast	150	175	75	150
10.15 a. m	200	100	75	200
Dinner	200	175	75	200
4 p. m	200	100	75	200
Suppper	150	175	75	150
9 p. m	200	100	72	200
10.20 p. m	150	75	....	150
Total	1,250	900	447	1,250

[a] Contained 803 grams water, 25 grams sugar, and 72 grams alcohol.

Daily routine.—The general plan of the series of experiments was identical with that of the previous series, and is shown in the following schedule:

Daily programme.—Metabolism experiments Nos. 32–34.

6.50 a. m	Take pulse and temperature.
7 a. m	Pass urine, weigh self dressed, collect drip, and weigh absorbers.
7.30 a. m	Breakfast, drink 150 grams water.
8.15 a. m	Begin work.
10.15 a. m	Stop work, drink 200 grams water.
10.30 a. m	Begin work.
12.30 p. m	Stop work.
12.50 p. m	Take pulse and temperature.
1 p. m	Pass urine, collect drip, and weigh absorbers.
1.25 p. m	Dinner, drink 200 grams water.
2 p. m	Begin work.
4 p. m	Stop work, drink 200 grams water.
4.15 p. m	Begin work.
6.15 p. m	Stop work, change underclothing.
6.20 p. m	Supper, drink 150 grams water.
6.50 p. m	Take pulse and temperature.
7 p. m	Pass urine, weigh self dressed, collect drip, and weigh absorbers.
9 p. m	Drink 200 grams water.
10 p. m	Take pulse and temperature.
10.10 p. m	Arrange bed.
10.20 p. m	Drink 150 grams water.
10.30 p. m	Retire.
1 a. m	Pass urine.

The more important statistics in the diary kept by the subject are summarized in Table XC. Frequent determinations of both pulse rate and body temperature were taken.

TABLE XC.—*Summary of diary—Metabolism experiments Nos. 32–34.*

Date and time.	Weight with clothes.	Pulse rate per minute.	Temperature.
1900.			
Experiment No. 32.	*Kilograms.*		*°F.*
Apr. 20, 6.55 a. m		66	
7 a. m	66.19		97.8
9 a. m		87	
10 a. m		83	
11 a. m		85	
12 m		82	
12.55 p. m		65	
1 p. m			97.7
2.05 p. m		93	
3 p. m		90	
4 p. m		87	
5 p. m		83	
6 p. m		84	
7 p. m	66.95	72	97.8
8 p. m		69	97.7
9 p. m		64	97.1
10 p. m		62	96.6
Apr. 21, 6.55 a. m		64	
7 a. m	66.36		97.8
9 a. m		91	
10 a. m		88	
11 a. m		89	
12 m		90	
1 p. m		67	98.0
2.15 p. m		94	
3 p. m		96	
4 p. m		97	
5 p. m		97	
6 p. m		85	
7 p. m	66.27	74	97.9
8.08 p. m		73	
8.15 p. m			97.5
9 p. m		67	97.1
10.05 p. m		66	
10.12 p. m			96.6
Apr. 22, 6.55 a. m		68	
7 a. m	65.83		97.7
9 a. m		101	
10 a. m		96	
11 a. m		92	
12 m		98	
1 p. m		68	97.7
2.05 p. m		100	
3 p. m		103	
4 p. m		104	
5 p. m		102	
6 p. m		100	
7 p. m	65.59	79	97.7
8 p. m		74	97.5
9 p. m		71	97.3
10.10 p. m		67	96.9
Experiment No. 33.			
Apr. 23, 6.55 a. m		69	
7 a. m	65.21		97.7
9 a. m		102	
9.02 a. m		106	
10 a. m		95	
11 a. m		96	
12 m		95	
1 p. m		70	98.0
1.57 p. m		73	
1900.			
Experiment No. 33—C't'd.	*Kilograms.*		*°F.*
Apr. 23, 2.05 p. m		97	
3 p. m		100	
4 p. m		102	
5 p. m		102	
6 p. m		97	
7 p. m	65.74	76	97.7
8 p. m		74	97.5
9 p. m		75	97.2
10.10 p. m		72	97.0
Apr. 24, 6.55 a. m		67	
7 a. m	65.27		97.8
9 a. m		109	
10 a. m		102	
11 a. m		96	
12 m		95	
1 p. m		72	97.9
2.07 p. m		98	
3 p. m		102	
4 p. m		108	
5 p. m		104	
6 p. m		100	
7 p. m	65.69	78	97.7
8 p. m		77	97.6
9 p. m		75	
9.04 p. m			97.1
10.10 p. m		71	
10.15 p. m			96.7
Apr. 25, 6.55 a. m		69	
7 a. m	65.13		97.7
9 a. m		109	
10 a. m		102	
11 a. m		101	
12 m		100	
1 p. m		74	97.9
2.05 p. m		102	
3 p. m		112	
4 p. m		107	
5 p. m		104	
6 p. m		105	
7 p. m	65.47	76	
8 p. m		76	97.8
9 p. m		78	97.6
10.10 p. m		75	97.2
Experiment No. 34.			
Apr. 26, 6.55 a. m		68	
7 a. m	64.94		97.7
9 a. m		106	
10 a. m		102	
11 a. m		96	
12 m		97	
1 p. m		66	97.7
2.05 p. m		98	
3 p. m		99	
4 p. m		97	
5 p. m		98	
6 p. m		97	
7 p. m	65.44	77	97.7
8 p. m		74	97.6
9 p. m		72	97.4
10.10 p. m		69	97.2
Apr. 27, 6.55 a. m		65	

TABLE XC.—*Summary of diary—Metabolism experiments Nos. 32–34*—Continued.

Date and time.	Weight with clothes.	Pulse rate per minute.	Temperature.
1900.			
Experiment No. 34—C't'd.			
	Kilograms.		*°F.*
Apr. 27, 7 a. m	65.09		97.6
9 a. m		103	
10 a. m		98	
11 a. m		100	
12 m		96	
1 p. m		71	98.3
2.05 p. m		100	
3 p. m		99	
4 p. m		99	
5 p. m		100	
6 p. m		97	
7 p. m	65.34	73	97.7
8 p. m		73	97.5
9 p. m		71	97.5
10 p. m		68	97.3
Apr. 28, 6.55 a. m		67	
7 a. m	64.98		97.9
1900.			
Experiment No. 34—C't'd.			
	Kilograms.		*°F.*
Apr. 28, 9 a. m		104	
10 a. m		98	
11 a. m		90	
12 m		93	
1 p. m		66	97.8
2.05 p. m		96	
3 p. m		97	
4 p. m		102	
5 p. m		99	
6 p. m		97	
7 p. m	65.37	73	97.0
8 p. m		75	97.5
9 p. m		67	97.4
10.10 p. m		69	97.3
Apr. 29, 6.55 a. m		69	
7 a. m	64.92		97.7

Amount of work done.—The total number of miles registered by the cyclometer and the heat equivalent of the work done each day are shown in Table XCI.

TABLE XCI.—*Record of work done—Metabolism experiments Nos. 32–34.*

Date and time.	Cyclometer reading.	Number of miles.	Actual duration of work.	Rate.	Heat equivalent.
1901.					
Experiment No. 32.			*Minutes.*	*Watts.*	*Calories.*
Apr. 20, 8.15 a. m	1,510.4				
10.15 a. m	1,527.2	16.8	120	18.8	32
12.30 p. m	1,546.5	19.3	120	21.0	36
4 p. m	1,562.8	16.3	120	16.7	29
6.15 p. m	1,579.1	16.3	120	17.4	30
Total		68.7	480		127
Apr. 21, 10.15 a. m	1,599.2	20.1	120	21.0	36
12.30 p. m	1,626.0	26.8	120	25.8	44
4 p. m	1,654.0	28.0	120	30.5	52
6.15 p. m	1,681.7	27.7	120	29.6	51
Total		102.6	480		183
Apr. 22, 10.15 a. m	1,711.6	29.9	120	36.2	62
12.30 p. m	1,744.6	33.0	120	47.4	81
4 p. m	1,774.5	29.9	120	38.1	65
6.15 p. m	1,806.1	31.6	120	40.0	69
Total		124.4	480		277
Experiment No. 33.					
Apr. 23, 10.15 a. m	1,825.3	19.2	120	20.6	35
12.30 p. m	1,854.1	28.8	120	23.9	41
4 p. m	1,880.8	26.7	120	26.6	46
6.15 p. m	1,908.2	27.4	120	27.5	47
Total		102.1	480		169

TABLE XCI.—*Record of work done—Metabolism experiments Nos. 32–34*—Continued.

Date and time.	Cyclometer reading.	Number of miles.	Actual duration of work.	Rate.	Heat equivalent.
1901.					
Experiment No. 33—Continued.			*Minutes.*	*Watts.*	*Calories.*
Apr. 24, 10.15 a. m	1,935.9	27.7	120	26.2	45
12.30 p. m	1,965.2	29.3	120	31.2	54
4 p. m	1,993.8	28.6	120	30.5	52
6.15 p. m	2,021.6	27.8	120	30.5	52
Total	....	113.4	480	....	203
Apr. 25, 10.15 a. m	2,049.3	27.7	120	29.6	51
12.30 p. m	2,079.2	29.9	120	33.3	57
4 p. m	2,108.1	28.9	120	31.6	54
6.15 p. m	2,138.0	29.9	120	33.7	58
Total	....	116.4	480	....	220
Experiment No. 34.					
Apr. 26, 10.15 a. m	2,166.9	28.9	120	34.3	59
12.30 p. m	2,196.7	29.8	120	35.4	60
4 p. m	2,226.1	29.4	120	34.3	59
6.15 p. m	2,254.1	28.0	120	33.7	58
Total	....	116.1	480	....	236
Apr. 27, 10.15 a. m	2,283.8	29.7	120	35.7	61
12.30 p. m	2,318.7	34.9	120	36.8	63
4 p. m	2,347.5	28.8	120	38.1	65
6.15 p. m	2,379.0	31.5	120	38.7	66
Total	....	124.9	480	....	255
Apr. 28, 10.15 a. m	2,409.6	30.6	120	37.4	64
12.30 p. m	2,441.5	31.9	120	38.1	65
4 p. m	2,472.6	31.1	120	38.1	65
6.15 p. m	2,503.8	31.2	120	38.1	65
Total	....	124.8	480	....	259

Detailed statistics of income and outgo.—The quantities of nutrients in the basal ration and the quantities in the supplemental rations for the different experiments are shown in Table XCII. The outgo of matter and energy in the feces during the different experiments is shown in Table XCIII.

TABLE XCII.—*Weight, composition, and heat of combustion of foods—Metabolism experiments Nos. 32–34.*

Laboratory No.	Food material.	Weight per day.	Water.	Protein.	Fat.	Carbohydrates.	Nitrogen.	Carbon.	Hydrogen.	Heat of combustion.
	Basal ration.	*Grams.*	*Grams.*	*Grams.*	*Grams.*	*Grams.*	*Grams.*	*Grams.*	*Grams.*	*Calories.*
3205	Beef	58	37.4	18.6	1.6	....	2.98	10.76	1.54	120
3206	Butter	35	2.9	.4	30.7	....	.07	22.95	3.63	287
3204	Bread	300	113.4	25.8	7.5	149.4	4.14	84.81	12.90	861
3207	Ginger snaps	75	2.8	4.1	5.4	61.2	.66	32.90	5.40	333
3193	Parched cereal	75	3.1	9.0	1.1	60.4	1.44	32.04	4.73	315
	Sugar	35	....	....	....	35.0	....	14.74	2.27	139
		578	159.6	57.9	46.3	306.0	9.29	198.20	30.47	2,055

TABLE XCII.—*Weight, composition, and heat of combustion of foods—Metabolism experiments Nos. 32-34*—Continued.

Laboratory No.	Food material.	Weight per day.	Water.	Protein.	Fat.	Carbohydrates.	Nitrogen.	Carbon.	Hydrogen.	Heat of combustion.
	EXPERIMENT NO. 32.	*Grams.*	*Grams.*	*Grams.*	*Grams.*	*Grams.*	*Grams.*	*Grams.*	*Grams.*	*Calories.*
3200	Milk, whole	1,020	871.1	41.8	51.0	47.9	6.73	81.09	12.14	923
	Total basal ration	1,598	1,030.7	99.7	97.3	353.9	16.02	279.29	42.61	2,978
	Supplemental ration.									
	Butter	62	5.2	.8	54.3	....	.12	40.66	6.43	509
	Total ration for 1 day	**1,660**	**1,035.9**	**100.5**	**151.6**	**353.9**	**16.14**	**319.95**	**49.04**	**3,487**
	EXPERIMENT NO. 33.									
3201	Milk, whole	1,020	868.0	41.8	53.0	49.0	6.73	83.84	12.65	922
	Total basal ration	1,598	1,027.6	99.7	99.3	355.0	16.02	282.04	43.12	2,977
	Supplemental ration.									
	Alcohol	72	....	....	....	....	....	37.56	9.39	509
	Total ration for 1 day	**1,670**	**1,027.6**	**99.7**	**99.3**	**355.0**	**16.02**	**319.60**	**52.51**	**3,486**
	EXPERIMENT NO. 34.									
3202	Milk, whole	1,020	869.0	41.8	53.0	43.9	6.73	83.64	12.34	931
	Total basal ration	1,598	1,028.6	99.7	99.3	349.9	16.02	281.84	42.81	2,986
	Supplemental ration.									
	Sugar	128	....	....	....	128.0	....	53.89	8.29	507
	Total ration for 1 day	**1,726**	**1,028.6**	**99.7**	**99.3**	**477.9**	**16.02**	**335.73**	**51.10**	**3,493**

TABLE XCIII.—*Weight, composition, and heat of combustion of feces—Metabolism experiments Nos. 32, 33, 34.*

Laboratory No.		Weight per day.	Water.	Protein.	Fat.	Carbohydrates.	Nitrogen.	Carbon.	Hydrogen.	Heat of combustion.
	Experiment No. 32.	*Grams.*	*Grams.*	*Grams.*	*Grams.*	*Grams.*	*Grams.*	*Grams.*	*Grams.*	*Calories.*
3209	Feces for 3 days	293.3	214.7	22.3	13.2	28.2	3.55	37.75	5.46	425
	Average per day	97.8	71.6	7.4	4.4	9.4	1.18	12.58	1.82	142
	Experiment No. 33.									
3210	Feces for 3 days	258.5	183.5	22.0	12.9	24.3	3.54	34.17	4.96	375
	Average per day	86.2	61.2	7.3	4.3	8.1	1.18	11.39	1.65	125
	Experiment No. 34.									
3211	Feces for 3 days	255.9	179.9	22.0	14.8	23.3	3.53	34.70	4.94	377
	Average per day	85.3	60.0	7.3	4.9	7.8	1.18	11.57	1.65	126

Table XCIV shows the quantity of urine eliminated on different days, and the quantity of urine and nitrogen in the urine for each 6-hour period of experiment No. 33. The heat of combustion of the urine was determined in the composite sample for each day and the carbon and hydrogen in the composite for the total 9 days of the series.

TABLE XCIV.—*Amounts, specific gravity, and nitrogen of urine—Metabolism experiments Nos. 32–34.*

Date.	Period.	Amount.	Specific gravity.	Nitrogen.	
1900.	*Experiment No. 32.*	*Grams.*		*Per cent.*	*Grams.*
Apr. 20–21	7 a. m. to 7 a. m.	1, 237. 6	1. 021	1. 28	15. 90
21–22	7 a. m. to 7 a. m.	1, 487. 9	1. 018	1. 01	14. 94
22–23	7 a. m. to 7 a. m.	1, 104. 1	1. 024	1. 38	15. 20
	Total				46. 04
	Experiment No. 33.				
Apr. 23–24	7 a. m. to 1 p. m.	256. 7	1. 025	1. 59	4. 08
	1 p. m. to 7 p. m.	425. 4	1. 019	1. 10	4. 68
	7 p. m. to 1 a. m.	239. 6	1. 025	1. 77	4. 24
	1 a. m. to 7 a. m.	167. 4	1. 026	1. 99	3. 33
	Total	1, 089. 1			16. 33
	Total by composite	1, 089. 1	1. 024	1. 50	16. 34
Apr. 24–25	7 a. m. to 1 p. m.	328. 1	1. 022	1. 28	4. 20
	1 p. m. to 7 p. m.	347. 6	1. 023	1. 40	4. 87
	7 p. m. to 1 a. m.	319. 2	1. 021	1. 51	4. 82
	1 a. m. to 7 a. m.	151. 0	1. 028	2. 17	3. 28
	Total	1, 145. 9			17. 17
	Total by composite	1, 145. 9	1. 024	1. 51	17. 30
Apr. 25–26	7 a. m. to 1 p. m.	262. 5	1. 025	1. 66	4. 36
	1 p. m. to 7 p. m.	337. 2	1. 024	1. 48	4. 99
	7 p. m. to 1 a. m.	242. 1	1. 026	1. 91	4. 62
	1 a. m. to 7 a. m.	147. 8	1. 030	2. 25	3. 33
	Total	989. 6			17. 30
	Total by composite	989. 6	1. 026	1. 75	17. 32
	Experiment No. 34.				
Apr. 26–27	7 a. m. to 7 a. m.	851. 4	1. 030	2. 00	17. 02
27–28	7 a. m. to 7 a. m.	909. 0	1. 026	1. 74	15. 86
28–29	7 a. m. to 7 a. m.	1, 095. 4	1. 024	1. 46	16. 04
	Total				48. 92

TABLE XCV.—*Daily elimination of carbon, hydrogen, and water in urine—Metabolism experiments Nos. 32–34.*

Date.	Amount.	Carbon.		Hydrogen.		Water.		Heat of combustion.	
								Per gram.	Total.
1900.	*Grams.*	*Per cent.*	*Grams.*	*Per cent.*	*Grams.*	*Per cent.*	*Grams.*	*Calories.*	*Calories.*
Apr. 20–21	1, 237. 6		11. 35		3. 13		1, 179. 7	0. 104	129
21–22	1, 487. 9		10. 67		2. 95		1, 433. 4	. 076	113
22–23	1, 104. 1		10. 85		3. 00		1, 048. 7	. 105	116
Total			32. 87		9. 08				358
23–24	1, 089. 1		11. 66		3. 22		1, 029. 6	. 115	125
24–25	1, 145. 9		12. 26		3. 38		1, 083. 3	. 113	129
25–26	989. 6		12. 35		3. 41		926. 6	. 134	133
Total			36. 27		10. 01				387
26–27	851. 4		12. 15		3. 36		789. 4	. 154	131
27–28	909. 0		11. 32		3. 13		851. 2	. 137	125
28–29	1, 095. 4		11. 45		3. 16		1, 036. 9	. 112	123
Total			34. 92		9. 65				379
Total 9 days	9, 910. 0	1. 05	104. 06	. 29	28. 74	94. 64		(. 112)	1, 124

Tables XCVI to XCVIII show the results of carbon dioxid and water in the ventilating air current. These statistics are given in detail for experiment No. 33, in which alcohol formed a part of the diet, and summarized for the other 2 experiments of the series. Similar statistics of the heat measurements are given in Table XCIX.

TABLE XCVI.—*Comparison of residual amounts of carbon dioxid and water in the chamber at the beginning and end of each period, and the corresponding gain or loss—Metabolism experiment No. 33.*

Date.	End of period.	Carbon dioxid.		Water.				
		Total amount in chamber.	Gain (+) or loss (−) over preceding period.	Total amount of vapor remaining in chamber.	Gain (+) or loss (−) over preceding period.	Change in weight of absorbers.[a] Gain (+) or loss (−).	Drip from absorbers.	Total amount gained (+) or lost (−) during the period.
1900.		*Grams.*	*Grams.*	*Grams.*	*Grams.*	*Grams.*	*Grams.*	*Grams.*
Apr. 23	7 a. m	27.0	....	46.7	....	....	....	....
23	1 p. m	82.8	+55.8	53.2	+6.5	+147	171.7	+325.2
23	7 p. m	80.2	− 2.6	52.1	−1.1	− 9	424.9	+414.8
24	1 a. m	29.5	−50.7	48.5	−3.6	− 74	31.0	− 46.6
24	7 a. m	28.5	− 1.0	48.1	− .4	− 73	31.0	− 42.4
	Total	....	+ 1.5	....	+1.4	− 9	658.6	+651.0
24	1 p. m	84.4	+55.9	54.5	+6.4	+172	263.4	+441.8
24	7 p. m	80.8	− 3.6	52.3	−2.2	− 28	434.3	+404.1
25	1 a. m	28.9	−51.9	48.8	−3.5	− 76	19.0	− 60.5
25	7 a. m	27.0	− 1.9	46.4	−2.4	− 76	19.0	− 59.4
	Total	....	− 1.5	....	−1.7	− 8	735.7	+726.0
25	1 p. m	85.7	+58.7	54.7	+8.3	+166	241.0	+415.3
25	7 p. m	85.7	....	53.0	−1.7	− 4	471.0	+465.3
26	1 a. m	27.6	−58.1	49.8	−3.2	− 82	24.0	− 61.2
26	7 a. m	26.0	− 1.6	46.0	−3.8	− 82	24.0	− 61.8
	Total	....	− 1.0	....	− .4	− 2	760.0	+757.6

TABLE XCVII.—*Record of carbon dioxid in ventilating air current—Metabolism experiments Nos. 32–34.*

Date.	Period.	(*a*)	Carbon dioxid.						(*h*)
		Ventilation. Number of liters of air.	In incoming air.		(*d*)	(*e*)	(*f*)	(*g*)	Total weight of carbon exhaled, $g\times\frac{3}{11}$.
			(*b*) Per liter.	(*c*) Total, $a\times b$.	In outgoing air.	Total excess in outgoing air, $d-c$.	Correction for amount remaining in chamber.	Corrected amount exhaled by subject, $e+f$.	
1900.	*Experiment No. 32.*	*Liters.*	*Mg.*	*Grams.*	*Grams.*	*Grams.*	*Grams.*	*Grams.*	*Grams.*
Apr. 20–21	7 a. m. to 7 a. m	107,275	....	66.1	1,145.8	1,079.7	+ .6	1,080.3	294.6
21–22	7 a. m. to 7 a. m	105,542	....	66.2	1,273.4	1,207.2	+ 2.8	1,210.0	329.9
22–23	7 a. m. to 7 a. m	106,320	....	63.4	1,359.1	1,295.7	− 3.4	1,292.3	352.4
	Experiment No. 33.								
23–24	7 a. m. to 1 p. m	25,952	0.583	15.1	383.8	368.7	+55.8	424.5	115.8
	1 p. m. to 7 p. m	25,175	.593	14.9	462.9	448.0	− 2.6	445.4	121.5
	7 p. m. to 1 a. m	26,430	.609	16.1	258.9	242.8	−50.7	192.1	52.3
	1 a. m. to 7 a. m	26,430	.600	15.9	158.5	142.6	− 1.0	141.6	38.6
	Total	103,987	....	62.0	1,264.1	1,202.1	+ 1.5	1,203.6	328.2
24–25	7 a. m. to 1 p. m	25,175	.598	15.1	406.6	391.5	+55.9	447.4	122.0
	1 p. m. to 7 p. m	26,730	.558	14.9	477.6	462.7	− 3.6	459.1	125.2
	7 p. m. to 1 a. m	27,208	.581	15.8	248.7	232.9	−51.9	181.0	49.4
	1 a. m. to 7 a. m	27,208	.642	17.5	154.1	136.6	− 1.9	134.7	36.7
	Total	106,321	....	63.3	1,287.0	1,223.7	− 1.5	1,222.2	333.3

[a] Absorbers not weighed between 7 p. m. and 7 a. m. The change in weight during this time is divided equally between the two periods.

TABLE XCVII.—*Record of carbon dioxid in ventilating air current—Metabolism experiments Nos. 32–34*—Continued.

Date.	Period.	(a) Ventilation. Number of liters of air.	Carbon dioxid. In incoming air. (b) Per liter.	(c) Total, $a \times b$.	(d) In outgoing air.	(e) Total excess in outgoing air, $d-c$.	(f) Correction for amount remaining in chamber.	(g) Corrected amount exhaled by subject, $e+f$.	(h) Total weight of carbon exhaled, $g \times \frac{3}{11}$.
1900.	*Experiment No. 33*—C't'd.								
		Liters.	*Mg.*	*Grams.*	*Grams.*	*Grams.*	*Grams.*	*Grams.*	*Grams.*
Apr. 25–26	7 a. m. to 1 p. m	25, 952	0. 587	15. 2	410. 0	394. 8	—58. 7	453. 5	123. 7
	1 p. m. to 7 p. m	25, 175	. 577	14. 5	478. 7	464. 2	....	464. 2	126. 6
	7 p. m. to 1 a. m	27, 985	. 580	16. 2	262. 9	246. 7	—58. 1	188. 6	51. 4
	1 a. m. to 7 a. m	27, 985	. 601	16. 8	153. 2	136. 4	— 1. 6	134. 8	36. 8
	Total	107, 097	....	62. 7	1, 304. 8	1, 242. 1	— 1. 0	1, 241. 1	338. 5
	Experiment No. 34.								
26–27	7 a. m. to 7 a. m	108, 654	....	64. 0	1, 305. 0	1, 241. 0	+ . 2	1, 241. 2	338. 5
27–28	7 a. m. to 7 a. m	114, 094	....	66. 1	1, 353. 1	1, 287. 0	— . 4	1, 286. 6	350. 9
28–29	7 a. m. to 7 a. m	114, 272	....	67. 0	1, 339. 7	1, 272. 7	— . 7	1, 272. 0	346. 9

TABLE XCVIII.—*Record of water in ventilating air current—Metabolism experiments Nos. 32–34.*

Date.	Period.	(a) Ventilation. Number of liters of air.	Water in incoming air. (b) Per liter.	(c) Total, $a \times b$.	Water in outgoing air. (d) Amount condensed in freezers.	(e) Amount not condensed in freezers.	(f) Total, $d+e$.	(g) Total excess water in outgoing air, $f-c$.	(h) Correction for water remaining in chamber.	(i) Total water of respiration and perspiration, $g+h$.
1900.	*Experiment No. 32.*									
		Liters.	*Mg.*	*Grams.*	*Grams.*	*Grams.*	*Grams.*	*Grams.*	*Grams.*	*Grams.*
Apr. 20–21	7 a. m. to 7 a. m..	107, 275	....	100. 9	894. 0	171. 0	1, 065. 0	964. 1	— 232. 8	1, 196. 9
21–22	7 a. m. to 7 a. m..	105, 542	....	100. 1	917. 2	181. 2	1, 098. 4	998. 3	+ 612. 1	1, 610. 4
22–23	7 a. m. to 7 a. m..	106, 320	....	110. 2	994. 8	176. 6	1, 171. 4	1, 061. 2	+1, 033. 1	2, 094. 3
	Experiment No. 33.									
23	7 a. m. to 1 p. m..	25, 952	1. 040	27. 0	235. 3	43. 5	278. 8	251. 8	+ 325. 2	577. 0
23	1 p. m. to 7 p. m..	25, 175	1. 137	28. 6	238. 6	43. 1	281. 7	253. 1	+ 414. 8	667. 9
23–24	7 p. m. to 1 a. m..	26, 430	1. 030	27. 2	233. 2	42. 7	275. 9	248. 7	— 46. 6	202. 1
24	1 a. m. to 7 a. m..	26, 430	. 930	24. 6	241. 3	40. 3	281. 6	257. 0	— 42. 4	214. 6
	Total......	103, 987	....	107. 4	948. 4	169. 6	1, 118. 0	1, 010. 6	— 651. 0	1, 661. 6
24	7 a. m. to 1 p. m..	25, 175	1. 088	27. 4	236. 1	44. 3	280. 4	253. 0	+ 441. 8	694. 8
24	1 p. m. to 7 p. m..	26, 730	1. 033	27. 6	250. 0	43. 9	293. 9	266. 3	— 404. 1	670. 4
24–25	7 p. m. to 1 a. m..	27, 208	. 923	25. 1	243. 9	43. 1	287. 0	261. 9	— 60. 5	201. 4
25	1 a. m. to 7 a. m..	27, 208	. 855	23. 3	246. 8	39. 0	285. 8	262. 5	— 59. 4	203. 1
	Total......	106, 321	....	103. 4	976. 8	170. 3	1, 147. 1	1, 043. 7	— 726. 0	1, 769. 7
25	7 a. m. to 1 p. m..	25, 952	. 951	24. 7	188. 9	44. 0	232. 9	208. 2	— 415. 3	623. 5
25	1 p. m. to 7 p. m..	25, 175	. 972	24. 5	253. 5	41. 7	295. 2	270. 7	+ 465. 3	736. 0
25–26	7 p. m. to 1 a. m..	27, 985	. 871	24. 4	243. 8	45. 9	289. 7	265. 3	— 61. 2	204. 1
26	1 a. m. to 7 a. m..	27, 985	. 783	21. 9	253. 1	38. 6	291. 7	269. 8	— 61. 8	208. 0
	Total......	107, 097	....	95. 5	939. 3	170. 2	1, 109. 5	1, 014. 0	— 757. 6	1, 771. 6
	Experiment No. 34.									
26–27	7 a. m. to 7 a. m..	108, 654	....	95. 6	995. 9	166. 6	1, 162. 5	1, 066. 9	+ 708. 9	1, 775. 8
27–28	7 a. m. to 7 a. m..	114, 094	....	100. 5	1, 026. 2	173. 8	1, 200. 0	1, 099. 5	+ 724. 8	1, 824. 3
28–29	7 a. m. to 7 a. m..	114, 272	....	105. 1	1, 021. 8	180. 5	1, 202. 3	1, 097. 2	+ 710. 4	1, 807. 6

TABLE XCIX.—*Summary of calorimetric measurements—Metabolism experiments Nos. 32–34.*

Date.	Period.	(a) Heat measured in terms of C_{20}.	(b) Change of temperature of calorimeter.	(c) Capacity correction of calorimeter $b \times 60$.	(d) Correction due to temperature of food and dishes.[a]	(e) Water vaporized equals total amount exhaled less amount condensed in chamber.	(f) Heat used in vaporization of water, $e \times 0.592$.	(g) Total heat determined, $a+c+d+f$.
1900.	*Experiment No. 32.*	*Calories.*	*Degrees.*	*Calories.*	*Calories.*	*Grams.*	*Calories.*	*Calories.*
Apr. 20–21	7 a. m. to 7 a. m	2,666.3	+0.32	+19.2	− 6.0	968.2	573.2	3,252.7
21–22	7 a. m. to 7 a. m	2,959.4	+ .07	+ 4.2	− 6.8	1,004.6	594.7	3,551.5
22–23	7 a. m. to 7 a. m	3,275.2			−12.4	1,058.5	626.7	3,889.5
	Experiment No. 33.							
23–24	7 a. m. to 1 p. m	1,088.6	+ .07	+ 4.2	− 3.3	258.3	152.9	1,242.4
	1 p. m. to 7 p. m	1,207.6	+ .01	+ 0.6	−14.4	252.0	149.2	1,343.0
	7 p. m. to 1 a. m	455.7			+ 1.2	245.1	145.1	602.0
	1 a. m. to 7 a. m	269.3	+ .01	+ 0.6		256.6	151.9	421.8
	Total	3,021.2	+ .09	+ 5.4	−16.5	1,012.0	599.1	3,609.2
24–25	7 a. m. to 1 p. m	1,153.8	− .04	− 2.4	− 5.1	259.4	153.5	1,299.8
	1 p. m. to 7 p. m	1,189.9	− .02	− 1.2	−15.3	264.1	156.3	1,329.7
	7 p. m. to 1 a. m	437.1			+ 1.4	258.4	153.0	591.5
	1 a. m. to 7 a. m	248.4	+ .01	+ 0.6		260.1	154.0	403.0
	Total	3,029.2	− .05	− 3.0	−19.0	1,042.0	616.8	3,624.0
25–26	7 a. m. to 1 p. m	1,180.4	− .04	− 2.4	− 2.5	216.5	128.2	1,303.7
	1 p. m. to 7 p. m	1,226.8			−10.4	269.0	159.2	1,375.6
	7 p. m. to 1 a. m	429.2			+ 2.3	262.1	155.2	586.7
	1 a. m. to 7 a. m	239.9	+ .01	+ 0.6		266.0	157.5	398.0
	Total	3,076.3	− .03	− 1.8	−10.6	1,013.6	600.1	3,664.0
	Experiment No. 34.							
26–27	7 a. m. to 7 a. m	2,948.7	− .07	− 4.2	− 7.7	1,067.1	631.7	3,568.5
27–28	7 a. m. to 7 a. m	2,989.9	− .11	− 6.6	− 0.7	1,098.3	650.2	3,632.8
28–29	7 a. m. to 7 a. m	2,924.1	− .01	− 0.6	−11.4	1,095.7	648.6	3,560.7

[a] Including 4.8 calories during each day period generated by the electric current used to magnetize the fields of the dynamo.

The alcohol, or reducing material equivalent to alcohol, given off from the body in different ways was determined in the usual manner, and the result appear in Table C. The usual correction is made for the total amount of reducing material in the urine, drip, freezer water, and air current, as found in experiments Nos. 32 and 34, in which alcohol did not form a part of the diet. It will be observed that about one-third of the total reducing material in experiment No. 33 must be considered as due to other compounds than the unoxidized alcohol. As in the previous series of experiments, there was no indication of a lag in the elimination of unoxidized alcohol.

TABLE C.—*Alcohol ingested and excreted—Metabolism experiments Nos. 32–34.*

Date.	Alcohol ingested.	Alcohol excreted, including other reducing material calculated as alcohol. In urine (distillate).	In drip (distillate).	In freezer water (distillate).	In air current.	Total.	Alcohol excreted unoxidized.[a]	Alcohol metabolized in body.	
1900.									
Experiment No. 32.	*Grams.*	*Grams.*	*Grams.*	*Grams.*	*Grams.*	*Grams.*	*Grams.*	*Grams.*	*Per cent.*
Apr. 20–21		0.02	0.02	0.01	0.41	0.44			
21–22		.01		Trace.	.30	.32			
22–23		.03		.01	.20	.25			

[a] Equals total reducing material excreted less 0.32 gram of reducing material not alcohol, the average for the days on which no alcohol was consumed.

TABLE C.—*Alcohol ingested and excreted—Metabolism experiments Nos. 32–34*—Continued.

Date.	Alcohol ingested.	Alcohol excreted, including other reducing material calculated as alcohol.					Alcohol excreted unoxidized.[a]	Alcohol metabolized in body.	
		In urine (distillate).	In drip (distillate).	In freezer water (distillate).	In air current.	Total.			
1900.									
Experiment No. 33.	*Grams.*	*Grams.*	*Grams.*	*Grams.*	*Grams.*	*Grams.*	*Grams.*	*Grams.*	*Per cent.*
Apr. 23–24	72.0	0.05		0.01	0.88	1.02	0.70	71.3	99.0
24–25	72.0	.06	0.22	.02	.92	1.07	.75	71.3	99.0
25–26	72.0	.05		.02	.93	1.07	.75	71.2	98.9
Total	216.0	.16	.22	.05	2.73	3.16	2.20	213.8	....
Average, 1 day	72.0	.05	.07	.01	.91	1.05	.73	71.3	99.0
Experiment No. 34.									
Apr. 26–27		.04		.01	.32	.37	....	....	....
27–28		.02	.04	.01	.26	.30	....	....	....
28–29		.01		.01	.20	.24	....	....	....

[a] Equals total reducing material excreted less 0.32 gram of reducing material not alcohol, the average for the days on which no alcohol was consumed.

Balance of income and outgo of matter and energy.—From the preceding statistics are computed the income and outgo of nitrogen, carbon, hydrogen, and energy on the different days of each of this series of experiments. The results of these computations are shown in Tables CI–CIV.

TABLE CI.—*Income and outgo of nitrogen and carbon—Metabolism experiments Nos. 32–34.*

Date and period.	Nitrogen.				Carbon.					
	(*a*) In food.	(*b*) In feces.	(*c*) In urine.[a]	(*d*) Gain (+) or loss (−), *a*−(*b*+*c*).	(*e*) In food.	(*f*) In feces.	(*g*) In urine.	(*h*) In respiratory products.	(*i*) In alcohol eliminated.	(*k*) Gain (+) or loss (−), *e*−(*f*+*g*+*h*+*i*).
1900.										
Experiment No. 32.	*Grams.*	*Grams.*	*Grams.*	*Grams.*	*Grams.*	*Grams.*	*Grams.*	*Grams.*	*Grams.*	*Grams.*
Apr. 20–21, 7 a. m. to 7 a. m.	16.1	1.2	16.3	−1.4	320.0	12.6	11.3	294.6	....	+ 1.5
21–22, 7 a. m. to 7 a. m.	16.2	1.2	15.3	− .3	320.0	12.6	10.7	329.9	....	− 33.2
22–23, 7 a. m. to 7 a. m.	16.1	1.2	15.6	− .7	320.0	12.6	10.9	352.4	....	− 55.9
Total	48.4	3.6	47.2	−2.4	960.0	37.8	32.9	976.9	....	− 87.6
Average, 1 day	16.1	1.2	15.7	− .8	320.0	12.6	11.0	325.6	....	− 29.2
Experiment No. 33.										
Apr. 23–24, 7 a. m. to 7 a. m.	16.0	1.2	16.7	−1.9	319.6	11.4	11.7	328.2	0.3	− 32.0
24–25, 7 a. m. to 7 a. m.	16.0	1.2	17.6	−2.8	319.6	11.4	12.3	333.3	.4	− 37.8
25–26, 7 a. m. to 7 a. m.	16.0	1.2	17.7	−2.9	319.6	11.4	12.3	338.5	.4	− 43.0
Total	48.0	3.6	52.0	−7.6	958.8	34.2	36.3	1,000.0	1.1	−112.8
Average, 1 day	16.0	1.2	17.3	−2.5	319.6	11.4	12.1	333.3	.4	− 37.6
Experiment No. 34.										
Apr. 26–27, 7 a. m. to 7 a. m.	16.0	1.2	17.4	−2.6	335.7	11.6	12.2	338.5	....	− 26.6
27–28, 7 a. m. to 7 a. m.	16.0	1.2	16.3	−1.5	335.8	11.5	11.3	350.9	....	− 37.9
28–29, 7 a. m. to 7 a. m.	16.0	1.2	16.4	−1.6	335.7	11.6	11.4	346.9	....	− 34.2
Total	48.0	3.6	50.1	−5.7	1,007.2	34.7	34.9	1,036.3	....	− 98.7
Average, 1 day	16.0	1.2	16.7	−1.9	335.7	11.6	11.6	345.4	....	− 32.9

[a] Nitrogen in perspiration, 0.4 grams per day, is included in this column.

TABLE CII.—*Income and outgo of water and hydrogen—Metabolism experiments Nos. 32–34.*

Date and period.	Water.						Hydrogen.						
	(a) In food.	(b) In drink.	(c) In feces.	(d) In urine.	(e) In respiratory products.	(f) Apparent loss. a+b−(c+d+e)	(g) In food.	(h) In feces.	(i) In urine.	(k) In alcohol eliminated.	(l) Apparent gain. g−(h+i+k).	(m) Loss from water. f÷9.	Total gain (+) or loss (−) l+m.
1900.													
Experiment No. 32.	*Grams.*	*Grams.*	*Grams.*	*Grams.*	*Grams.*	*Grams.*	*Grams.*	*Gms.*	*Gms.*	*Grams.*	*Grams.*	*Grams.*	*Grams.*
Apr. 20–21, 7 a. m. to 7 a. m.	1,035.9	1,250	71.6	1,179.7	1,196.9	162.3	49.0	1.8	3.1	......	+ 44.1	− 18.0	+26.1
Apr. 21–22, 7 a. m. to 7 a. m.	1,035.9	1,250	71.5	1,433.4	1,610.4	829.4	49.0	1.8	3.0	......	+ 44.2	− 92.2	−48.0
Apr. 22–23, 7 a. m. to 7 a. m.	1,035.9	1,250	71.6	1,048.7	2,094.3	928.7	49.0	1.8	3.0	......	+ 44.2	−103.2	−59.0
Total	3,107.7	3,750	214.7	3,661.8	4,901.6	1,920.4	147.0	5.4	9.1	......	+132.5	−213.4	−80.9
Average, 1 day	1,035.9	1,250	71.6	1,220.6	1,633.8	640.1	49.0	1.8	3.0	......	+ 44.2	− 71.1	−26.9
Experiment No. 33.													
Apr. 23–24, 7 a. m. to 7 a. m.	1,027.6	1,250	61.2	1,029.6	1,661.6	474.8	52.5	1.6	3.2	0.1	+ 47.6	− 52.8	− 5.2
Apr. 24–25, 7 a. m. to 7 a. m.	1,027.6	1,250	61.1	1,083.3	1,769.7	636.5	52.5	1.7	3.4	.1	+ 47.3	− 70.7	−23.4
Apr. 25–26, 7 a. m. to 7 a. m.	1,027.6	1,250	61.2	926.6	1,771.6	481.8	52.5	1.6	3.4	.1	+ 47.4	− 53.5	− 6.1
Total	3,082.8	3,750	183.5	3,039.5	5,202.9	1,593.1	157.5	4.9	10.0	.3	+142.3	−177.0	−34.7
Average, 1 day	1,027.6	1,250	61.2	1,013.2	1,734.3	531.0	52.5	1.6	3.4	.1	+ 47.4	− 59.0	−11.6
Experiment No. 34.													
Apr. 26–27, 7 a. m. to 7 a. m.	1,028.6	1,250	60.0	789.4	1,775.8	346.6	51.1	1.7	3.4	......	+ 46.0	− 38.5	+ 7.5
Apr. 27–28, 7 a. m. to 7 a. m.	1,028.6	1,250	59.9	851.2	1,824.3	456.8	51.1	1.6	3.1	......	+ 46.4	− 50.8	− 4.4
Apr. 28–29, 7 a. m. to 7 a. m.	1,028.6	1,250	60.0	1,036.9	1,807.6	625.9	51.1	1.7	3.2	......	+ 46.2	− 69.5	−23.3
Total	3,085.8	3,750	179.9	2,677.5	5,407.7	1,429.3	153.3	5.0	9.7	......	138.6	−158.8	−20.2
Average, 1 day	1,028.6	1,250	60.0	892.5	1,802.5	476.4	51.1	1.7	3.2	......	46.2	− 52.9	− 6.7

TABLE CIII.—*Gain or loss of protein (N×6.25), fat, and water—Metabolism experiments Nos. 32–34.*

Date and period.	(a) Nitrogen gained (+) or lost (−).	(b) Protein gained (+) or lost (−), a×6.25.	(c) Total carbon gained (+) or lost (−).	(d) Carbon in protein gained (+) or lost (−), b×0.53.	(e) Carbon in fat, etc., gained (+) or lost (−), c−d.	(f) Fat gained (+) or lost (−), e÷0.761.	(g) Total hydrogen gained (+) or lost (−).	(h) Hydrogen in protein gained (+) or lost, (−) b×0.07.	(i) Hydrogen in fat gained (+) or lost (−) f×0.118.	(k) Hydrogen in water, etc., gained (+) or lost (−), g−(h+i).	(l) Water gained (+) or lost (−), k×9.
1900.											
Experiment No. 32.	*Grams.*	*Grams.*	*Grams.*	*Grams.*	*Grams.*	*Grams.*	*Grams.*	*Grams.*	*Grams.*	*Grams.*	*Grams.*
Apr. 20–21, 7 a. m. to 7 a. m.	−1.4	− 8.7	+ 1.5	− 4.6	+ 6.1	+ 8.0	+26.1	−0.6	+ 0.9	+25.8	+232.2
21–22, 7 a. m. to 7 a. m.	− .3	− 1.9	− 33.2	− 1.0	−32.2	− 42.3	−48.0	− .1	− 5.0	−42.9	−386.1
22–23, 7 a. m. to 7 a. m.	− .7	− 4.4	− 55.9	− 2.3	−53.6	− 70.4	−59.0	− .3	− 8.3	−50.4	−453.6
Total	−2.4	−15.0	− 87.6	− 7.9	−79.7	−104.7	−80.9	−1.0	−12.4	−67.5	−607.5
Average, 1 day	− .8	− 5.0	− 29.2	− 2.6	−26.6	− 34.9	−26.9	− .3	− 4.1	−22.5	−202.5
Experiment No. 33.											
Apr. 23–24, 7 a. m to 7 a. m.	−1.9	−11.9	− 32.0	− 6.3	−25.7	− 33.8	− 5.2	− .8	− 4.0	− .4	− 3.6
24–25, 7 a. m to 7 a. m.	−2.8	−17.5	− 37.8	− 9.3	−28.5	− 37.5	−23.4	−1.2	− 4.4	−17.8	−160.2
25–26, 7 a. m to 7 a. m.	−2.9	−18.1	− 43.0	− 9.6	−33.4	− 43.9	− 6.1	−1.3	− 5.2	+ .4	+ 3.6
Total	−7.6	−47.5	−112.8	−25.2	−87.6	−115.2	−34.7	−3.3	−13.6	−17.8	−160.2
Average, 1 day	−2.5	−15.8	− 37.6	− 8.4	−29.2	− 38.4	−11.5	−1.1	− 4.5	− 5.9	− 53.1
Experiment No. 34.											
Apr. 26–27, 7 a. m. to 7 a. m.	−2.6	−16.3	− 26.6	− 8.6	−18.0	− 23.7	+ 7.5	−1.1	− 2.8	+11.4	+102.6
27–28, 7 a. m. to 7 a. m.	−1.5	− 9.4	− 37.9	− 5.0	−32.9	− 43.2	− 4.4	− .7	− 5.1	+ 1.4	+ 12.6
28–29, 7 a. m. to 7 a. m.	−1.6	−10.0	− 34.2	− 5.3	−28.9	− 38.0	−23.3	− .7	− 4.5	−18.1	−162.9
Total	−5.7	−35.7	− 98.7	−18.9	−79.8	−104.9	−20.2	−2.5	−12.4	− 5.3	− 47.7
Average, 1 day	−1.9	−11.9	− 32.9	− 6.3	−26.6	− 35.0	− 6.7	− .8	− 4.1	− 1.8	− 15.9

TABLE CIV.—*Income and outgo of energy—Metabolism experiments Nos. 32–34.*

Date and period.	(a) Heat of combustion of food eaten.	(b) Heat of combustion of feces.	(c) Heat of combustion of urine.	(m) Heat of combustion of alcohol eliminated.	(d) Estimated heat of combustion of protein gained (+) or lost (−).	(e) Estimated heat of combustion of fat gained (+) or lost (−).	(f) Estimated energy of material oxidized in the body, a−(b+c+m+d+e).	(g) Heat determined.	Heat determined greater (+) or less (−) than estimated. (h) f−g.	(i) h÷f.
1900.										
Experiment No. 32.	*Calories.*	*Calories.*	*Calories.*	*Calories.*	*Calories.*	*Calories.*	*Calories.*	*Calories.*	*Calories.*	*Per cent.*
Apr. 20–21, 7 a. m. to 7 a. m.	3,487	142	129	....	− 35	+ 77	3,174	3,253	+ 79	+2.5
21–22, 7 a. m. to 7 a. m.	3,487	141	113	....	+ 3	− 404	3,634	3,551	− 83	−2.3
22–23, 7 a. m. to 7 a. m.	3,487	142	116	....	− 11	− 672	3,912	3,890	− 22	− .5
Total	10,461	425	358	....	− 43	− 999	10,720	10,694	− 26	....
Average, 1 day	3,487	142	119	....	− 14	− 333	3,573	3,565	− 8	− .2
Experiment No. 33.										
Apr. 23–24, 7 a. m. to 7 a. m.	3,486	125	125	5	− 54	− 322	3,607	3,609	+ 2	.0
24–25, 7 a. m. to 7 a. m.	3,486	125	129	5	− 86	− 357	3,670	3,624	− 46	−1.3
25–26, 7 a. m. to 7 a. m.	3,486	125	133	5	− 90	− 419	3,732	3,664	− 68	−1.8
Total	10,458	375	387	15	−230	−1,098	11,009	10,897	−112	....
Average, 1 day	3,486	125	129	5	− 76	− 366	3,669	3,632	− 37	−1.0
Experiment No. 34.										
Apr. 26–27, 7 a. m. to 7 a. m.	3,493	126	131	....	− 79	− 226	3,541	3,568	+ 27	+ .7
27–28, 7 a. m. to 7 a. m.	3,493	125	125	....	− 40	− 413	3,696	3,633	− 63	−1.7
28–29, 7 a. m. to 7 a. m.	3,493	126	123	....	− 43	− 363	3,650	3,561	− 89	−2.4
Total	10,479	377	379	....	−162	−1,002	10,887	10,762	−125	....
Average, 1 day	3,493	126	126	....	− 54	− 334	3,629	3,587	− 42	−1.1

STATISTICAL DETAILS OF DIGESTION EXPERIMENTS.

As has already been explained, each metabolism experiment or series of experiments was preceded by a digestion experiment and each metabolism experiment includes a digestion experiment. The results of those digestion experiments in which alcohol formed a part of the diet are detailed herewith. Those of the corresponding experiments without alcohol are given in connection with the description of the latter, as elsewhere published.[a] The results of the digestion experiments with and without alcohol are summarized beyond.

The weights of the different food materials, as shown in the first column of Tables CV–CVIII, together with the figures for percentage, composition, and heat of combustion, as shown in Tables I–III above, suffice for the computations of the nutrients and energy in the food and feces. In computing the protein from the nitrogen, the factor 6.25 has been used for all animal foods and 5.70 for the vegetable foods used in the experiments.[b] The total organic matter as shown in the tables is the sum of the organic constituents—protein, fat, carbohydrates, and alcohol.

DETAILS OF DIGESTION EXPERIMENT NO. 41.

This was preliminary to metabolism experiment No. 7, began with breakfast June 3, 1897, and continued 5 days. The diet was the same in kind and practically the same in the relative amounts of the different ingredients as in the following metabolism experiment. The subject was E. O., the laboratory assistant who served in a large number of the experiments here recorded. His weight at the beginning of the experiment was not recorded; at the end it was without clothing, 66.7 kilograms (147 pounds). He was occupied in his usual duties about the laboratory, but did as little muscular work as practicable, in order that the conditions of exercise should not differ greatly from those in the following rest experiment in the respiration apparatus. The results of the experiment are shown in Table CV.

DETAILS OF DIGESTION EXPERIMENT NO. 42.

This experiment followed immediately after No. 41 and formed a part of metabolism experiment No. 7. It began with breakfast June 8, 1898, and continued 4 days. The subject, E. O., weighed without clothing 66.7 kilograms (147 pounds) at the beginning and 66 kilograms (145½ pounds) at the end of the study. The subject had as little muscular activity as was practicable during the experiment. The details are given in Table CVI.

TABLE CV.—*Details of digestion experiment No. 41 (preliminary to metabolism experiment No. 7).*

Laboratory No. sample.		Weight of material.	Total organic matter.	Nitrogen.	Protein.	Fat.	Carbohydrates.	Alcohol.	Ash.	Heat of combustion (determined).
		Grams.	*Grams.*	*Grams.*	*Grams.*	*Grams.*	*Grams.*	*Grams.*	*Grams.*	*Calories.*
2795	Beef, fried	850	274	34.7	217	57			11	1,709
2796	Beef, dried	125	34	4.8	30	4			9	199
2798	Eggs, boiled	722	138	11.5	72	66			5	1,028
2801	Butter	75	65	.2	1	64			3	595
2800	Milk	2,875	351	16.2	101	138	112		22	2,133
2804	Bread, rye	750	420	10.1	58	4	358		12	1,862
2786	Sugar	225	225				225			891
2797	Beans, baked	625	169	6.2	39	6	124		12	786
	Pears, canned	750	145	.3	2	4	139		2	577
	Alcohol	363	363					362.5		2,566
	Total	7,360	2,184	84	520	343	958	362.5	76	12,346
2809	Feces	404	96	7.7	48	22	26		19	632
	Alcohol excreted unoxidized		15					15		106
	Urine									590
	Amount available		2,073	76.3	472	321	932	347.5	57	11,018
			Per cent.	*Per cent.*	*Per cent.*	*Per cent.*	*Per cent.*	*Per cent.*	*Per cent.*	*Per cent.*
	Coefficients of availability		94.9	90.8	90.8	93.6	97.3	95.9	75	89.2

[a] See page 241.

[b] See discussion of nitrogen factor for protein. ATWATER and BRYANT, Rept. Storrs (Conn.) Expt. Sta., 1899, p. 76.

TABLE CVI.—*Details of digestion experiment No. 42 (part of metabolism experiment No. 7).*

Laboratory No. sample.		Weight of material.	Total organic matter.	Nitrogen.	Protein.	Fat.	Carbohydrates.	Alcohol.	Ash.	Heat of combustion (determined).
		Grams.	*Grams.*	*Grams.*	*Grams.*	*Grams.*	*Grams.*	*Grams.*	*Grams.*	*Calories.*
2795	Beef, fried	675	217	27.5	172	45	....	....	9	1,357
2796	Beef, dried	100	27	3.8	24	3	....	....	7	160
2798	Eggs, boiled	564	108	9.1	57	51	....	....	4	803
2801	Butter	60	52	.2	1	51	....	....	2	476
2800	Milk	2,300	281	13	81	110	90	....	18	1,707
2804	Bread, rye	600	336	8	46	4	286	....	10	1,490
2786	Sugar	180	180	....	....	....	180	....	....	713
2797	Beans, baked	500	135	5	31	5	99	....	10	628
	Pears, canned	600	116	.3	2	3	111	....	1	461
	Alcohol	290	290	....	....	....	....	290	....	2,050
	Total	5,869	1,742	66.9	414	272	766	290	61	9,845
2810	Feces	198	47	3.5	22	10	15	....	10	303
	Alcohol excreted unoxidized	....	11.9	....	....	....	....	11.9	....	84
	Urine	....	....	....	....	....	....	....	....	490
	Amount available	....	1,683.1	63.4	392	262	751	278.1	51	8,968
			Per cent.	*Per cent.*	*Per cent.*	*Per cent.*	*Per cent.*	*Per cent.*	*Per cent.*	*Per cent.*
	Coefficients of availability	....	96.6	94.8	94.7	96.3	98.1	95.9	83.6	91.1

DETAILS OF DIGESTION EXPERIMENT NO. 47.

This experiment began with breakfast February 11, 1898, and continued 4 days. The diet was the same in kind and practically the same in amount as in metabolism experiment No. 10, which immediately followed and of which this experiment formed the preliminary period. The subject, E. O., weighed without clothing 67.4 kilograms (148½ pounds) at the close of the study. His weight at the beginning was not recorded. He was engaged about the laboratory in his usual occupation, but avoided muscular exertion so far as practicable. Table CVII gives the details.

DETAILS OF DIGESTION EXPERIMENT NO. 48.

This experiment, which formed a part of metabolism experiment No. 10, began with breakfast February 15, 1898, and continued 4 days. The subject, E. O., weighed without clothing 67.4 kilograms at the beginning and 67.6 kilograms (149 pounds) at the end of the experimental period. Table CVIII gives detailed results.

TABLE CVII.—*Details of digestion experiment No. 47 (preliminary to metabolism experiment No. 10).*

Lab. No. sample.		Weight of material.	Total organic matter.	Nitrogen.	Protein.	Fat.	Carbohydrates.	Alcohol.	Ash.	Heat of combustion (determined).
		Grams.	*Grams.*	*Grams.*	*Grams.*	*Grams.*	*Grams.*	*Grams.*	*Grams.*	*Calories.*
2839	Beef	1,080	329.0	46.9	293	36	....	....	21	1,961
2843	Butter	60	53.0	....	....	53	....	....	1	479
2845	Milk, skimmed	3,000	261.0	14.9	93	3	165	....	24	1,206
2844	Bread	500	288.0	6.7	38	1	249	....	7	1,277
2842	Maize breakfast food	200	187.0	3.8	23	16	148	....	3	887
2840	Wheat breakfast food	200	182.0	3.5	20	3	159	....	4	810
2841	Ginger snaps	240	223.0	2.2	13	15	195	....	7	1,019
	Sugar	280	280.0	....	....	....	280	....	....	1,109
	Alcohol	290	290.0	....	....	....	....	290.0	....	2,050
	Total	5,850	2,093.0	78.0	480	127	1,196	290.0	67	10,798
2847	Feces	267	59.0	4.0	25	10	24	....	12	360
	Alcohol excreted unoxidized	....	4.4	....	....	....	....	4.4	....	31
	Urine	....	....	....	....	....	....	....	....	569
	Amount available	....	2,029.6	74.0	455	117	1,172	285.6	55	9,838
			Per cent.	*Per cent.*	*Per cent.*	*Per cent.*	*Per cent.*	*Per cent.*	*Per cent.*	*Per cent.*
	Coefficients of availability	....	97.0	94.9	94.8	92.1	98.0	98.5	82.1	91.1

TABLE CVIII.—*Details of digestion experiment No. 48 (part of metabolism experiment No. 10).*

Lab. No. sample.		Weight of material.	Total organic matter.	Nitrogen.	Protein.	Fat.	Carbohydrates.	Alcohol.	Ash.	Heat of combustion (determined).
		Grams.	*Grams.*	*Grams.*	*Grams.*	*Grams.*	*Grams.*	*Grams.*	*Grams.*	*Calories.*
2839	Beef	1,080	329.0	46.9	293	36			21	1,961
2843	Butter	60	53.0			53			1	479
2846	Milk, skimmed	3,000	264.0	15.8	99	3	162		24	1,242
2844	Bread	500	288.0	6.7	38	1	249		7	1,277
2842	Maize breakfast food	200	187.0	3.8	23	16	148		3	887
2840	Wheat breakfast food	200	182.0	3.5	20	3	159		4	810
2841	Ginger snaps	240	223.0	2.2	13	15	195		7	1,019
	Sugar	280	280.0				280			1,109
	Alcohol	290	290.0					290.0		2,050
	Total	5,850	2,096.0	78.9	486	127	1,193	290.0	67	10,834
2848	Feces	351	85.0	5.4	34	15	36		17	507
	Alcohol excreted unoxidized		4.4					4.4		31
	Urine									565
	Amount available		2,006.6	73.5	452	112	1,157	285.6	50	9,731
			Per cent.	*Per cent.*	*Per cent.*	*Per cent.*	*Per cent.*	*Per cent.*	*Per cent.*	*Per cent.*
	Coefficients of availability		95.7	93.1	93.0	88.2	97.0	98.5	74.6	89.8

DETAILS OF DIGESTION EXPERIMENT NO. 51.

This study was preliminary to metabolism experiment No. 12, with the same kinds and amounts of the different food materials. The subject, E. O., was engaged in his usual laboratory work, but in addition took considerable muscular exercise on the bicycle and otherwise, in order to make the conditions of muscular activity not greatly different from those in the following metabolism experiment. The study began with breakfast April 8, 1898, and continued 4 days. The subject weighed, without clothing, 70.5 kilograms (155.4 pounds) at the beginning and 70.1 kilograms (154.5 pounds) at the end of the study.

DETAILS OF DIGESTION EXPERIMENT NO. 52.

This experiment, which formed a part of metabolism experiment No. 12, began with breakfast April 12, 1898, and continued 4 days. The subject, E. O., weighed, without clothing, 70.9 kilograms (156.3 pounds) at the beginning and 70.3 kilograms (155 pounds) at the end of the study. He worked 8 hours a day upon a stationary bicycle within the chamber of the calorimeter.

TABLE CIX.—*Details of digestion experiment No. 51 (preliminary to metabolism experiment No. 12).*

Lab. No. sample.		Weight of material.	Total organic matter.	Nitrogen.	Protein.	Fat.	Carbohydrates.	Alcohol.	Ash.	Heat of combustion (determined).
		Grams.	*Grams.*	*Grams.*	*Grams.*	*Grams.*	*Grams.*	*Grams.*	*Grams.*	*Calories.*
2860	Beef	700	231.0	30.7	192	39			18	1,400
2861	Butter	380	330.0	.3	2	328			8	3,004
2856	Milk	3,600	482.0	19.0	119	180	183		25	3,114
2859	Bread	1,200	702.0	18.1	103	12	587		13	3,196
2842	Maize breakfast food	240	224.0	4.5	27	20	177		4	1,065
2858	Deviled ham	200	110.0	5.9	37	73			8	873
	Sugar	280	280.0				280			1,109
	Alcohol	290	290.0					290.0		2,050
	Total	6,890	2,649.0	78.5	480	652	1,227	290.0	76	15,811
2862	Feces	495	120.0	7.2	45	38	37		27	791
	Alcohol excreted unoxidized		6.0					6.0		42
	Urine									544
	Amount available		2,523.0	71.3	435	614	1,190	284.0	49	14,434
			Per cent.	*Per cent.*	*Per cent.*	*Per cent.*	*Per cent.*	*Per cent.*	*Per cent.*	*Per cent.*
	Coefficients of availability		95.2	90.8	90.6	94.2	97.0	97.9	64.5	91.3

TABLE CX.—*Details of digestion experiment No. 52 (part of metabolism experiment No. 12).*

Lab. No. sample.		Weight of material.	Total organic matter.	Nitrogen.	Protein.	Fat.	Carbohydrates.	Alcohol.	Ash.	Heat of combustion (determined).
		Grams.	*Grams.*	*Grams.*	*Grams.*	*Grams.*	*Grams.*	*Grams.*	*Grams.*	*Calories.*
2866	Beef	700	231.0	30.7	192	39			18	1,400
2861	Butter	380	330.0	0.3	2	328			8	3,004
2857	Milk	3,600	425.0	17.9	112	162	151		25	2,873
2859	Bread	1,200	702.0	18.1	103	12	587		13	3,196
2842	Maize breakfast food	240	224.0	4.5	27	20	177		4	1,065
2858	Deviled ham	200	110.0	5.9	37	73			8	873
	Sugar	280	280.0				280			1,109
	Alcohol	290	290.0					290.0		2,050
	Total	6,890	2,592.0	77.4	473	634	1,195	290.0	76	15,570
2863	Feces	370	79.0	5.0	31	26	22		16	545
	Alcohol excreted unoxidized		6.0					6.0		42
	Urine									553
	Amount available		2,507.0	72.4	442	608	1,173	284.0	60	14,430
			Per cent.	*Per cent.*	*Per cent.*	*Per cent.*	*Per cent.*	*Per cent.*	*Per cent.*	*Per cent.*
	Coefficients of availability		96.7	93.5	93.4	95.9	98.2	97.9	78.9	92.7

DETAILS OR DIGESTION EXPERIMENT NO. 80.

This experiment formed the preliminary period to the series of metabolism experiments Nos. 15–17. It began with breakfast January 12, 1899, and continued 4 days. The subject, E. O., as in previous experiments here reported, was engaged in very light work about the laboratory. His weight at the end of the study, without clothing, was 70.9 kilograms (156 pounds). The alcohol during this period was taken in the form of commercial alcohol in sweetened coffee infusion, as in metabolism experiment No. 15. In metabolism experiment No. 16 the alcohol was taken in the form of whisky, and in No. 17 in the form of brandy.

DETAILS OF DIGESTION EXPERIMENT NO. 81.

This experiment, which formed a part of the series of metabolism experiments Nos. 15, 16, and 17, began with breakfast January 16, 1899, and continued 6 days. The subject, E. O., weighed, without clothing, 70.9 kilograms at the beginning and 70.1 kilograms (154.5 pounds) at the end of the experiment.

TABLE CXI.—*Details of digestion experiment No. 80 (preliminary to metabolism experiment No. 15).*

Laboratory No. sample.		Weight of material.	Total organic matter.	Nitrogen.	Protein.	Fat.	Carbohydrates.	Alcohol.	Ash.	Heat of combustion (determined).
		Grams.	*Grams.*	*Grams.*	*Grams.*	*Grams.*	*Grams.*	*Grams.*	*Grams.*	*Calories.*
3009	Beef	640	184	26.7	167	17			14	1,076
3003	Butter	120	104	.2	1	103			3	955
3005	Milk, skimmed	3,450	334	22.1	138	3	193		31	1,611
3004	Parched cereal	120	111	2.2	13	1	97		2	487
2968	Bread	1,240	707	15.7	89	35	583		16	3,360
	Sugar	204	204				204			808
	Alcohol	290	290					290		2,256
	Total	6,064	1,934	66.9	408	159	1,077	290	66	10,553
	Feces	185	55	3.2	20	13	22		14	383
3007	Alcohol excreted unoxidized		6.8					6.8		48
	Urine									485
	Amount available		1,872.2	63.7	388	146	1,055	283.2	52	9,637
			Per cent.	*Per cent.*	*Per cent.*	*Per cent.*	*Per cent.*	*Per cent.*	*Per cent.*	*Per cent.*
	Coefficients of availability		96.8	95.2	95.1	91.8	98	97.6	78.8	91.4

TABLE CXII.—*Details of digestion experiment No. 81 (part of metabolism experiments Nos. 15, 16, and 17).*

Laboratory No. sample.		Weight of material.	Total organic matter.	Nitrogen.	Protein.	Fat.	Carbohydrates.	Alcohol.	Ash.	Heat of combustion (determined).
		Grams.	*Grams.*	*Grams.*	*Grams.*	*Grams.*	*Grams.*	*Grams.*	*Grams.*	*Calories.*
3009	Beef	960	275	40.0	250	25	....	....	21	1,615
3003	Butter	180	157	.3	2	155	....	....	5	1,433
3006	Milk, skimmed	5,700	553	37.5	234	6	313	....	46	2,667
3004	Parched cereal	180	166	3.2	18	1	147	....	3	730
2968	Bread	1,860	1,060	23.5	134	52	874	....	24	5,040
	Sugar	342	342	....	....	....	342	....	....	1,354
	Alcohol	435	435	....	....	....	....	435	....	3,075
	Total	9,657	2,988	104.5	638	239	1,676	435	99	15,914
3008	Feces	316	76	5	31	18	27	....	24	529
	Alcohol excreted unoxidized	....	10.3	....	....	....	....	10.3	....	73
	Urine	....	....	....	....	....	....	....	....	759
	Amount available	....	2,901.7	99.5	607	221	1,649	424.7	75	14,553
			Per cent.	*Per cent.*	*Per cent.*	*Per cent.*	*Per cent.*	*Per cent.*	*Per cent.*	*Per cent.*
	Coefficients of availability	....	97.1	95.2	95.2	92.5	98.4	97.6	75.8	91.5

DETAILS OF DIGESTION EXPERIMENT NO. 82.

This experiment was preliminary to and formed a part of metabolism experiments Nos. 18–21. The subject was A. W. S., a physicist. He was engaged in the investigations of which this experiment forms a part. The study began with breakfast February 2, 1899, and continued 4 days outside the apparatus. During the following 9 days, beginning with February 6, the subject was inside the respiration chamber. It was the intention to subdivide the 13 days covered by this digestion experiment into three separate experiments, comprising the 4 preliminary days previous to the time when the subject entered the respiration calorimeter; the 6 days in the calorimeter in which alcohol formed a part of the diet, either as commercial alcohol, whisky, or brandy; and the 3 days of experiment No. 21 in which alcohol was omitted from the diet. Unfortunately no satisfactory separation of the feces was obtained between the preliminary period and the end of the experiment No. 21. The whole time is therefore included in one digestion experiment. The body weight of the subject at the beginning of the period was 72.4 kilograms, and at the end 72.7 kilograms (160.3 pounds). During the preliminary days very little muscular work was done, and during the sojourn in the apparatus practically no exercise was taken. The kinds and daily amounts of foods were the same during the 4 preliminary days, and the 6 days of metabolism experiments Nos. 18–20, except that alcohol was taken in the form of commercial ethyl alcohol in the preliminary period and in No. 18, whisky in No. 19, brandy in No. 20. In experiment No. 21 the alcohol was omitted from the diet.

TABLE CXIII.—*Details of digestion experiment No. 82 (preliminary to and part of metabolism experiments Nos. 18–21).*

Laboratory No. sample.		Weight of material.	Total organic matter.	Nitrogen.	Protein.	Fat.	Carbohydrates.	Alcohol.	Ash.	Heat of combustion (determined).
		Grams.	*Grams.*	*Grams.*	*Grams.*	*Grams.*	*Grams.*	*Grams.*	*Grams.*	*Calories.*
3022	Beef	2,080	634	92.9	581	53			43	3,800
3021	Butter	390	341	.7	4	337			10	3,148
3023–4	Milk	9,750	1,232	49.6	310	430	492		78	7,658
3004	Parched cereal	390	360	7.2	41	2	317		6	1,582
2968	Bread	4,030	2,297	50.9	290	113	1,894		52	10,921
	Sugar	585	585				585			2,317
	Alcohol	725	725					725		5,331
	Total	17,950	6,174	201.3	1,226	935	3,288	725	189	34,757
3033	Feces	832	188	13.5	84	52	52		39	1,307
	Alcohol excreted unoxidized		24.5					24.5		173
	Urine									1,427
	Amount available	17,118	5,961.5	187.8	1,142	883	3,236	700.5	150	31,850
			Per cent.	*Per cent.*	*Per cent.*	*Per cent.*	*Per cent.*	*Per cent.*	*Per cent.*	*Per cent.*
	Coefficients of availability		96.6	93.8	93.2	94.4	98.4	96.6	79.4	91.6

DETAILS OF DIGESTION EXPERIMENT NO. 83.

This experiment began with breakfast March 9, 1899, and continued 4 days. It was preliminary to the series of metabolism experiments Nos. 22–24, and was made with the same subject, E. O., who served in the majority of the digestion experiments here described. The diet during the first 3 days contained no alcohol. On the last day 72.5 grams of absolute alcohol were added in the form of commercial ethyl alcohol. The subject was engaged in his usual work about the laboratory and performed very little manual labor. His weight, without clothing, was 72.4 kilograms (159.6 pounds) at the close of the experiment.

DETAILS OF DIGESTION EXPERIMENT NO. 84.

The experiment began with breakfast March 13, 1899, and continued 6 days, forming a part of metabolism experiment Nos. 22 and 23, details of which are given above. Alcohol formed a part of the diet on the first 3 days (metabolism experiment No. 22) while on the last 3 days (metabolism experiment No. 23) only the basal ration was eaten. The subject, E. O., weighed, without clothing, at the beginning of the experiment 72.4 kilograms and at the end 72.7 kilograms (160.3 pounds). He had as little muscular activity during the series of experiments as was practicable.

TABLE CXIV.—*Details of digestion experiment No. 83 (preliminary to metabolism experiment No. 22).*

Laboratory No. sample.		Weight of material.	Total organic matter.	Nitrogen.	Protein.	Fat.	Carbohydrates.	Alcohol.	Ash.	Heat of combustion (determined).
		Grams.	*Grams.*	*Grams.*	*Grams.*	*Grams.*	*Grams.*	*Grams.*	*Grams.*	*Calories.*
3027	Beef	600	246.0	33.4	209	37			6	1,580
3029	Butter	220	193.0	.3	2	191			6	1,766
3031	Milk, skimmed	4,520	384.0	26.1	163	4	217		36	1,849
3004	Cereal, parched	180	166.0	3.2	18	1	147		3	730
3032	Bread	1,240	723.0	15.7	89	42	592		16	3,483
	Sugar	160	160.0				160			634
	Alcohol	72	72.0					72.0		509
3069	Horse-radish	98	9.0	.2	1		8		1	37
	Total	7,090	1,953.0	78.9	482	275	1,124	72.0	68	10,588
3034	Feces	267	64.0	4.6	29	15	20		19	417
	Alcohol excreted unoxidized		2.2					2.2		16
	Urine									566
	Amount available		1,886.8	74.3	453	260	1,104	69.8	49	9,589
			Per cent.	*Per cent.*	*Per cent.*	*Per cent.*	*Per cent.*	*Per cent.*	*Per cent.*	*Per cent.*
	Coefficients of availability		96.6	94.2	94.0	94.5	98.2	97.0	72.1	90.5

TABLE CXV.—*Details of digestion experiment No. 84 (part of metabolism experiments Nos. 22 and 23).*

Laboratory No. sample.		Weight of material.	Total organic matter.	Nitrogen.	Protein.	Fat.	Carbohydrates.	Alcohol.	Ash.	Heat of combustion (determined).
		Grams.	*Grams.*	*Grams.*	*Grams.*	*Grams.*	*Grams.*	*Grams.*	*Grams.*	*Calories.*
3027	Beef	900	369.0	50.2	314	55			9	2,370
3029	Butter	330	290.0	.7	4	286			8	2,649
3031	Milk, skimmed	6,780	576.0	39.0	244	7	325		54	2,773
3004	Cereal, parched	270	249.0	5.0	28	1	220		4	1,095
3032	Bread	1,860	1,084.0	23.5	134	63	887		24	5,225
	Sugar	240	240.0				240			950
	Alcohol	216	216.0					216		1,526
3069	Horse-radish	90	8.0	.2	1		7		1	34
	Total	10,686	3,032.0	118.6	725	412	1,679	216	100	16,622
3035	Feces	426	100.0	6.7	42	22	36		30	686
	Alcohol excreted unoxidized		6.6					6.6		47
	Urine									854
	Amount available		2,925.4	111.9	683	390	1,643	209.4	70	15,035
			Per cent.	*Per cent.*	*Per cent.*	*Per cent.*	*Per cent.*	*Per cent.*	*Per cent.*	*Per cent.*
	Coefficients of availability		96.5	94.4	94.2	94.7	97.9	97.0	70.0	90.5

DETAILS OF DIGESTION EXPERIMENT NO. 151.

This experiment formed a part of metabolism experiment No. 27 in series 26–28, studying the comparative effects of fat, alcohol, and sugar in the diet. The subject, J. F. S., was a chemist engaged in the investigation here reported. His weight, in underclothing, was 64.1 kilograms at the beginning and 63.7 kilograms (140.4 pounds) at the end of the study. The experiment began with breakfast February 17, 1900, and continued 3 days.

TABLE CXVI.—*Details of digestion experiment No. 151 (part of metabolism experiment No. 27).*

Laboratory No. sample.		Weight of material.	Total organic matter.	Nitrogen.	Protein.	Fat.	Carbohydrates.	Alcohol.	Ash.	Heat of combustion (determined).
		Grams.	*Grams.*	*Grams.*	*Grams.*	*Grams.*	*Grams.*	*Grams.*	*Grams.*	*Calories.*
3176	Beef	255	93.0	13.8	86	7			2	560
3177	Butter	90	78.0	.2	1	77			2	720
3179	Milk, skimmed	3,000	276.0	20.1	126	9	141		24	1,386
3180	Bread	600	356.0	8.5	49	10	297		8	1,682
3181	Ginger snaps	180	170.0	1.8	10	15	145		3	798
3168	Parched cereal	150	140.0	2.8	16	3	121		3	620
	Sugar	45	45.0				45			178
	Alcohol	216	216.0					216.0		1,526
	Total	4,536	1,374.0	47.2	288	121	749	216.0	42	7,470
3184	Feces	219	48.0	3.4	21	6	21		18	292
	Alcohol excreted unoxidized		2.7					2.7		19
	Urine									334
	Amount available		1,323.3	43.8	267	115	728	213.3	24	6,825
			Per cent.	*Per cent.*	*Per cent.*	*Per cent.*	*Per cent.*	*Per cent.*	*Per cent.*	*Per cent.*
	Coefficients of availability		96.3	92.8	92.7	95.0	97.2	98.7	57.1	91.4

DETAILS OF DIGESTION EXPERIMENT NO. 155.

This experiment formed a part of metabolism experiment No. 30, the second of the series of experiments Nos. 29–31 for the purpose of studying the relative effect of sugar, alcohol, and fat in the diet during periods of work. It began with breakfast March 19, 1900, and continued 3 days. The subject was J. F. S. His weight, in underclothing, was 64.6 kilograms at the beginning and 64.1 kilograms (141.3 pounds) at the end of the experiment.

TABLE CXVII.—*Details of digestion experiment No. 155 (part of metabolism experiment No. 30).*

Laboratory No. sample.		Weight of material.	Total organic matter.	Nitrogen.	Protein.	Fat.	Carbohydrates.	Alcohol.	Ash.	Heat of combustion (determined).
		Grams.	*Grams.*	*Grams.*	*Grams.*	*Grams.*	*Grams.*	*Grams.*	*Grams.*	*Calories.*
3186	Beef	174	67.0	10.0	62	5	....	....	2	405
3187	Butter	141	124.0	.3	2	122	....	....	5	1,135
3190	Milk	2,700	384.0	17.3	108	146	130	....	22	2,430
3192	Bread	900	560.0	13.5	77	18	465	....	12	2,637
3181	Ginger snaps	225	213.0	2.3	13	19	181	....	4	998
3193	Parched cereal	225	211.0	4.3	25	3	183	....	5	945
	Sugar	75	75.0	....	....	....	75	....	....	297
	Alcohol	216	216.0	....	....	....	....	216.0	....	1,526
	Total	4,656	1,850.0	47.7	287	313	1,034	216.0	50	10,373
3196	Feces	143	33.0	2	13	6	14	....	8	213
	Alcohol excreted unoxidized	....	2.3	....	....	....	....	2.3	....	16
	Urine	....	....	....	....	....	....	....	....	343
	Amount available	....	1,814.7	45.7	274	307	1,020	213.7	42	9,801
			Per cent.	*Per cent.*	*Per cent.*	*Per cent.*	*Per cent.*	*Per cent.*	*Per cent.*	*Per cent.*
	Coefficients of availability	....	98.1	95.8	95.5	98.1	98.6	98.9	84	94.5

DETAILS OF DIGESTION EXPERIMENT NO. 159.

This experiment, which began with breakfast, April 23, 1900, and continued 3 days, formed a part of the series of metabolism experiments Nos. 32–34, studying the relative effect of fat, alcohol, and sugar in the diet during periods of work. The subject was the same as in the two preceding experiments here described. His weight, in underclothing, was 65.2 kilograms at the beginning and 64.9 kilograms (143.1 pounds) at the end of the investigation.

TABLE CXVIII.—*Details of digestion experiment No. 159 (part of metabolism experiment No. 33).*

Lab. No. sample.		Weight of material.	Total organic matter.	Nitrogen.	Protein.	Fat.	Carbohydrates.	Alcohol.	Ash.	Heat of combustion (determined).
		Grams.	*Grams.*	*Grams.*	*Grams.*	*Grams.*	*Grams.*	*Grams.*	*Grams.*	*Calories.*
3205	Beef	174	61.0	8.9	56	5	....	....	2	361
3206	Butter	105	93.0	.2	1	92	....	....	3	862
3201	Milk	3,060	432.0	20.2	126	159	147	....	24	2,766
3204	Bread	900	548.0	12.4	71	23	454	....	12	2,582
3207	Ginger snaps	225	212.0	2.0	11	16	185	....	5	998
3193	Parched cereal	225	211.0	4.3	25	3	183	....	5	945
	Sugar	105	105.0	....	....	....	105	....	....	416
	Alcohol	216	216.0	....	....	....	....	216.0	....	1,526
	Total	5,010	1,878.0	48.0	290	298	1,074	216.0	51	10,456
	Feces	259	59.0	3.5	22	13	24	....	16	375
	Alcohol excreted, unoxidized	....	2.2	....	....	....	....	2.2	....	16
	Urine	....	....	....	....	....	....	....	....	335
	Amount available	....	1,816.8	44.5	268	285	1,050	213.8	35	9,730
			Per cent.	*Per cent.*	*Per cent.*	*Per cent.*	*Per cent.*	*Per cent.*	*Per cent.*	*Per cent.*
	Coefficients of availability	....	96.7	92.7	92.4	95.6	97.8	99.0	68.6	93.1

TABULAR SUMMARIES OF RESULTS OF THE EXPERIMENTS.

The following tables summarize the more important results of the experiments.

INCOME AND OUTGO OF NITROGEN AND GAIN OR LOSS OF PROTEIN AND FAT.

The data which bear immediately upon the nitrogen and carbon balance, and the gains and losses of protein and fat, with and without alcohol in the ration, are brought together in Table CXIX. The method of grouping was explained above, page —.

TABLE CXIX.—*Income and outgo of nitrogen and carbon and gain or loss of protein and fat, in experiments with and without alcohol.*

Classification, serial numbers, and subjects of experiments.	Duration.	In daily food. Protein.	Fat.	Carbohydrates.	Alcohol.	Energy.	Nitrogen. (a) In food.	(b) In feces.	(c) In urine.	(d) Gain (+) or loss (−), $d=a-(b+c)$.	(e) Protein, gain (+) or loss (−), $e=d \times 6.25$.	Carbon. (f) In food.	(g) In feces.	(h) In urine.	(i) In alcohol eliminated.	(k) In respiratory products.	(l) Gain (+) or loss (−), $l=f-(g+h+i+k)$.	(m) Fat, gain (+) or loss (−), $m=(l-.53e) \div .765$.
Experiments with and without alcohol more strictly comparable.																		
REST EXPERIMENTS.																		
GROUP A.	*D.*	*Gs.*	*Gms.*	*Gms.*	*Gms.*	*Cals.*	*Gms.*	*Gms.*	*Gms.*	*Gms.*	*Gms.*	*Gms.*	*Gms.*	*Gms.*	*Gms.*	*Gms.*	*Gms.*	*Gms.*
No. 9, E. O., ordinary diet	4	119	69	342	....	2,717	19.1	1.3	18.4	−0.6	− 3.6	261.6	13.4	12.6	....	223.6	+12.0	+18.2
No. 10, E. O., alcohol diet	4	123	32	297	72.5	2,709	19.8	1.4	19.5	−1.1	− 6.9	253.3	11.8	13.5	0.5	214.9	+12.6	+21.2
GROUP B.																		
No. 24, E. O., ordinary diet	3	124	69	409	....	3,061	19.8	1.3	18.2	+ .3	+ 1.7	299.7	10.5	11.8	....	230.9	+46.5	+59.7
No. 22, E. O., alcohol diet	3	124	69	276	72.0	3,044	19.8	1.1	18.5	+ .2	+ 1.4	279.8	10.3	11.8	1.2	207.8	+48.7	+62.7
GROUPS A–B.																		
Average, 9, 24, ordinary diet	7	121	69	375	....	2,889	19.4	1.3	18.3	− .2	− 1.0	280.7	11.9	12.2	....	227.3	+29.3	+39.0
Average, 10, 22, alcohol diet	7	123	51	286	72.3	2,877	19.8	1.3	19.0	− .5	− 2.8	266.6	11.1	12.7	.8	211.4	+30.6	+42.0
GROUP C.																		
No. 26, J. F. S., ordinary diet	3	100	95	247	....	2,490	15.9	1.1	15.4	− .6	− 3.5	233.2	9.4	11.0	....	196.1	+16.7	+24.4
No. 28, J. F. S., ordinary diet	3	99	40	375	....	2,489	15.8	1.2	15.3	− .7	− 4.5	245.8	10.0	10.9	....	210.7	+14.2	+21.8
Average, 26, 28	6	99	68	311	....	2,490	15.9	1.2	15.3	− .6	− 4.0	239.5	9.7	11.0	....	203.4	+15.4	+23.1
No. 27, J. F. S., alcohol diet	3	99	40	247	72.0	2,491	15.8	1.1	15.7	−1.0	− 6.0	229.5	8.9	11.2	.5	198.3	+10.6	+18.3

TABLE CXIX.—*Income and outgo of nitrogen and carbon and gain or loss of protein and fat, etc.*—Continued.

Classification, serial numbers, and subjects of experiments.	Duration.	In daily food. Protein.	In daily food. Fat.	In daily food. Carbohydrates.	In daily food. Alcohol.	In daily food. Energy.	Nitrogen. (a) In food.	Nitrogen. (b) In feces.	Nitrogen. (c) In urine.	Nitrogen. (d) Gain (+) or loss (−), $d=a-(b+c)$.	(e) Protein, gain (+) or loss (−), $e=d\times 6.25$.	Carbon. (f) In food.	Carbon. (g) In feces.	Carbon. (h) In urine.	Carbon. (i) In alcohol eliminated.	Carbon. (k) In respiratory products.	Carbon. (l) Gain (+) or loss (−), $l=f-(g+h+i+k)$.	(m) Fat, gain (+) or loss (−), $m=(l-.53e)\div.765$.
Experiments with and without alcohol more strictly comparable—Continued.																		
REST EXPERIMENTS—Continued.																		
GROUPS A–C.	*D.*	*Gs.*	*Gms.*	*Gms.*	*Gms.*	*Cals.*	*Gms.*	*Gms.*	*Gms.*	*Gms.*	*Gms.*	*Gms.*	*Gms.*	*Gms.*	*Gms.*	*Gms.*	*Gms.*	*Gms.*
Average, 9, 24, 26+28, ordinary diet	13	114	69	354	....	2,756	18.3	1.3	17.3	−0.3	− 2.0	266.9	11.2	11.8	....	219.3	+24.6	+33.7
Average, 10, 22, 27, alcohol diet	10	115	47	273	72.2	2,748	18.5	1.2	17.9	− .6	− 3.8	254.2	10.3	12.2	0.7	207.0	+24.0	+34.1
WORK EXPERIMENTS.																		
GROUP D.																		
No. 11, E. O., ordinary diet	4	124	129	485	....	3,862	19.8	2.2	18.1	− .5	− 3.0	373.5	20.2	12.7	....	372.6	−32.0	−39.7
No. 12, E. O., alcohol diet	4	121	159	296	72.4	3,891	19.3	1.3	18.2	− .2	− 1.0	344.8	12.1	12.3	.8	344.7	−25.1	−32.2
GROUP E.																		
No. 29, J. F. S., ordinary diet	3	100	106	471	....	3,487	16.0	.8	16.0	− .8	− 5.0	333.6	8.3	11.2	....	334.9	−20.8	−23.8
No. 31, J. F. S., ordinary diet	3	101	161	343	....	3,495	16.1	.8	15.6	− .3	− 2.3	321.5	8.1	10.9	....	315.8	−13.3	−15.9
Average, 29, 31	6	100	134	407	....	3,491	16.0	.8	15.8	− .6	− 3.7	327.6	8.2	11.1	....	325.4	−17.1	−19.9
No. 30, J. F. S., alcohol diet	3	99	104	341	72.0	3,458	15.9	.7	17.3	−2.1	−13.1	315.5	6.4	12.1	.4	316.5	−19.9	−17.0
GROUP F.																		
No. 32, J. F. S., ordinary diet	3	101	152	354	....	3,487	16.1	1.2	15.7	− .8	− 5.0	320.0	12.6	11.0	....	325.6	−29.2	−34.9
No. 34, J. F. S., ordinary diet	3	100	99	478	....	3,493	16.0	1.2	16.7	−1.9	−11.9	335.7	11.6	11.6	....	345.4	−32.9	−35.0
Average, 32, 34	6	100	126	416	....	3,490	16.0	1.2	16.2	−1.4	− 8.5	327.8	12.1	11.3	....	335.5	−31.1	−35.0
No. 33, J. F. S., alcohol diet	3	100	99	355	72.0	3,486	16.0	1.2	17.3	−2.5	−15.8	319.6	11.4	12.1	.4	333.3	−37.6	−38.4
GROUPS E–F.																		
Average, 29+31, 32+34, ordinary diet	12	100	130	412	....	3,490	16.0	1.0	16.0	−1.0	− 6.1	327.7	10.2	11.2	....	330.4	−24.1	−27.5
Average, 30, 33, alcohol diet	6	100	102	348	72.0	3,472	16.0	1.0	17.3	−2.3	−14.5	317.6	8.9	12.1	.4	324.9	−28.7	−27.7
GROUPS D–F.																		
Average, 11, 29+31, 32+34, ordinary diet	16	108	130	436	....	3,614	17.3	1.4	16.7	− .8	− 5.1	343.0	13.5	11.7	....	344.5	−26.7	−31.5
Average, 12, 30, 33, alcohol diet	10	107	21	331	72.2	3,611	17.1	1.1	17.6	−1.6	−10.0	326.6	10.0	12.2	.5	331.5	−27.5	−29.2

TABLE CXIX.—*Income and outgo of nitrogen and carbon and gain or loss of protein and fat, etc.*—Continued.

Classification, serial numbers, and subjects of experiments.	In daily food.						Nitrogen.				(e)	Carbon.						(m)
	Duration.	Protein.	Fat.	Carbohydrates.	Alcohol.	Energy.	(a) In food.	(b) In feces.	(c) In urine.	(d) Gain (+) or loss (−), d=a−(b+c).	Protein, gain (+) or loss (−), e=d×6.25.	(f) In food.	(g) In feces.	(h) In urine.	(i) In alcohol eliminated.	(k) In respiratory products.	(l) Gain (+) or loss (−), l=f−(g+h+i+k).	Fat, gain (+) or loss (−), m=(l−.53e)÷.765.
Experiments with and without alcohol less strictly comparable.																		
REST EXPERIMENTS.																		
GROUP G.	D.	Gs.	Gms.	Gms.	Gms.	Cals.	Gms.	Gms.	Gms.	Gms.	Gms.	Gms.	Gms.	Gms.	Gms.	Gms.	Gms.	Gms.
No. 13, E. O., ordinary diet	3	117	88	270	....	2,596	18.7	1.1	19.5	−1.9	−11.7	245.8	11.1	15.1	....	205.2	−14.4	−26.9
No. 14, E. O., ordinary diet	4	94	83	290	....	2,513	15.1	.9	16.2	−2.0	−12.4	239.0	7.4	12.2	....	207.3	−12.1	−24.4
Average, 13, 14	7	105	86	280	....	2,555	16.9	1.0	17.8	−1.9	−12.0	242.4	9.3	13.6	....	206.3	−13.2	−25.7
No. 7, E. O., alcohol diet	4	104	68	191	72.5	2,462	16.7	.9	17.7	−1.9	−12.0	218.6	6.7	13.3	1.5	214.5	−17.4	−14.3
GROUP H.																		
No. 5, E. O., ordinary diet	4	119	95	276	....	2,655	19.1	1.7	18.1	− .7	− 4.2	248.9	13.8	11.6	....	231.7	− 8.2	− 7.8
No. 15, E. O., alcohol diet	2	109	40	277	72.5	2,653	17.4	.8	15.6	−1.0	− 6.0	245.7	7.8	11.0	.8	220.0	− 6.1	− 3.8
No. 16, E. O., alcohol diet	2	109	40	277	72.5	2,653	17.4	.8	15.5	−1.1	− 7.2	245.7	7.8	10.9	1.1	218.3	− 7.6	− 5.0
No. 17, E. O., alcohol diet	2	109	40	277	72.5	2,653	17.4	.8	15.6	−1.0	− 6.0	245.7	7.8	11.0	.8	214.5	−11.6	−11.0
Average, 15, 16, 17	6	109	40	277	72.5	2,653	17.4	.8	15.6	−1.1	− 6.4	245.7	7.8	11.0	.9	217.6	− 8.4	− 6.6
GROUP I.																		
No. 21, A. W. S., ordinary diet	3	97	72	250	....	2,264	15.5	1.0	15.4	− .9	− 5.6	215.2	9.0	10.8	....	217.4	−22.0	−24.9
No. 18, A. W. S., alcohol diet	2	97	72	250	72.5	2,776	15.5	1.1	16.4	−2.0	−12.2	253.0	9.0	10.4	1.6	219.3	−12.7	−25.1
No. 19, A. W. S., alcohol diet	2	97	72	250	72.5	2,776	15.5	1.0	14.5	0	0	253.0	9.0	9.2	1.3	206.6	−26.9	−35.1
No. 20, A. W. S., alcohol diet	2	97	72	250	72.5	2,776	15.5	1.0	14.1	− .4	− 2.2	253.0	9.0	9.0	1.5	216.2	−17.3	−21.1
Average, 18, 19, 20	6	97	72	250	72.5	2,776	15.5	1.0	15.0	− .5	− 3.3	253.0	9.0	9.5	1.5	214.1	−18.9	−27.1
GROUPS G–I.																		
Average, 13–14, 5, 21, ordinary diet	14	107	84	269	....	2,491	17.1	1.2	17.1	−1.2	− 7.3	235.5	10.7	12.0	....	218.5	− 5.7	− 2.3
Average, 7, 15 to 17, 18 to 20, alcohol diet	16	103	60	239	72.5	2,630	16.5	.9	16.1	− .5	− 3.0	239.1	7.8	11.3	1.3	215.4	− 3.3	− 6.5
GROUPS A–I.																		
Average, 9, 24, 26–28, 11, 29–31, 32–34, 13–14, 5, 21, ordinary diet	43	110	94	353	....	2,954	17.5	1.3	17.0	− .8	− 4.8	281.8	11.8	11.8	....	260.8	− 2.6	− .1
Average, 10, 22, 27, 12, 30, 33, 7, 15 to 17, 18 to 20, alcohol diet	36	108	76	281	72.3	2,997	17.4	1.1	17.2	− .9	− 5.6	273.3	9.4	11.9	.8	251.3	− .1	+ 3.8

INCOME AND OUTGO OF MATERIAL AND ENERGY.

Table CXX compares the available protein and energy, the gain or loss of body protein and body fat, and the energy of material oxidized in the body and that measured as heat and muscular work in the various groups of experiments with and without alcohol. The available protein is the difference between the protein in the food and that in the feces, while the available energy represents the energy of the food less the energy of the feces and (dry matter of) urine. The energy of the material oxidized in the body represents what may be called the net income, while the energy measured as heat and muscular work may be called the net outgo.

TABLE CXX.—*Material and energy supplied and metabolized in experiments with and without alcohol.*

[Quantities per day.]

Classification, serial numbers, and subject of experiments.	Available protein.	Available energy.	Gain (+) or loss (−) of body material.		Energy of material oxidized in the body.	Energy measured as—		
			Protein.	Fat.		Heat.	Muscular work.	Total.
Experiments with and without alcohol more strictly comparable.								
REST EXPERIMENTS.								
GROUP A.	*Grams.*	*Calories.*	*Grams.*	*Grams.*	*Calories.*	*Calories.*	*Calories.*	*Calories.*
No. 9, E. O., ordinary diet	112	2,426	− 3.6	+18.2	2,277	2,309	....	2,309
No. 10, E. O., alcohol diet	115	2,427	− 6.9	+21.2	2,268	2,283	....	2,283
GROUP B.								
No. 24, E. O., ordinary diet	115	2,809	+ 1.7	+59.7	2,238	2,272	....	2,272
No. 22, E. O., alcohol diet	117	2,777	+ 1.4	+62.7	2,180	2,258	....	2,258
GROUPS A AND B.								
Average 9, 24, E. O., ordinary diet	114	2,618	− 1.0	+39.0	2,258	2,291	....	2,291
Average 10, 22, E. O., alcohol diet	116	2,602	− 2.8	+42.0	2,224	2,270	....	2,270
GROUP C.								
No. 26, J. F. S., ordinary diet	93	2,256	− 3.5	+24.4	2,043	2,085	....	2,085
No. 28, J. F. S., ordinary diet	91	2,249	− 4.5	+21.8	2,067	2,079	....	2,079
Average 26, 28	92	2,253	− 4.0	+23.1	2,055	2,082	....	2,082
No. 27, J. F. S., alcohol diet	92	2,264	− 6.0	+18.2	2,125	2,123	....	2,123
GROUPS A, B, AND C.								
Average 9, 24, 26+28, ordinary diet	106	2,496	− 2.0	+33.7	2,190	2,221	....	2,221
Average 10, 22, 27, alcohol diet	108	2,489	− 3.8	+34.1	2,191	2,221	....	2,221
WORK EXPERIMENTS.								
GROUP D.								
No. 11, E. O., ordinary diet	110	3,510	− 3.0	−39.7	3,901	3,746	186	3,932
No. 12, E. O., alcohol diet	113	3,614	− 1.0	−32.2	3,922	3,727	200	3,927
GROUP E.								
No. 29, J. F. S., ordinary diet	95	3,260	− 5.0	−23.8	3,515	3,334	255	3,589
No. 31, J. F. S., ordinary diet	96	3,275	− 2.3	−15.9	3,439	3,171	249	3,420
Average 29, 31	96	3,268	− 3.7	−19.9	3,477	3,253	252	3,505
No. 30, J. F. S., alcohol diet	95	3,242	−13.1	−17.0	3,479	3,321	249	3,470
GROUP F.								
No. 32, J. F. S., ordinary diet	93	3,226	− 5.0	−34.9	3,573	3,369	196	3,565
No. 34, J. F. S., ordinary diet	92	3,241	−11.9	−35.0	3,629	3,337	250	3,587
Average 32, 34	93	3,234	− 8.5	−35.0	3,601	3,353	223	3,576
No. 33, J. F. S., alcohol diet	92	3,227	−15.8	−38.4	3,669	3,435	197	3,632

TABLE CXX.—*Material and energy supplied and metabolized in experiments with and without alcohol*—Continued.

Classification, serial numbers, and subject of experiments.	Available protein.	Available energy.	Gain (+) or loss (−) of body material. Protein.	Gain (+) or loss (−) of body material. Fat.	Energy of material oxidized in the body.	Energy measured as— Heat.	Energy measured as— Muscular work.	Energy measured as— Total.
Experiments with and without alcohol more strictly comparable—Continued.								
REST EXPERIMENTS—Continued.								
GROUPS E AND F.	*Grams.*	*Calories.*	*Grams.*	*Grams.*	*Calories.*	*Calories.*	*Calories.*	*Calories.*
Average 29–31, 32–34, ordinary diet	95	3, 251	− 6. 1	−27. 5	3, 539	3, 303	238	3, 541
Average 30, 33, alcohol diet	94	3, 235	−14. 5	−27. 7	3, 574	3, 328	223	3, 551
GROUPS D, E, AND F.								
Average 11, 29–31, 32–34, ordinary diet	100	3, 337	− 5. 1	−31. 5	3, 660	3, 451	220	3, 671
Average 12, 30, 33, alcohol diet	100	3, 361	−10. 0	−29. 2	3, 690	3, 461	215	3, 676
GROUPS A TO F.								
Average 9, 24, 26–28, 11, 29–31, 32–34, ordinary diet	103	2, 917	− 3. 5	+ 1. 1	2, 925	2, 836	110	2, 946
Average 10, 22, 27, 12, 30, 33, alcohol diet	104	2, 925	− 6. 9	+ 2. 4	2, 941	2, 841	108	2, 949
Experiments with and without alcohol less strictly comparable.								
REST EXPERIMENTS.								
GROUP G.								
No. 13, E. O., ordinary diet	110	2, 298	−11. 7	+26. 9	2, 112	2, 151	....	2, 151
No. 14, E. O., ordinary diet	89	2, 289	−12. 4	+24. 4	2, 131	2, 193	....	2, 193
Average 13, 14	100	2, 294	−12. 0	+25. 7	2, 121	2, 172	....	2, 172
No. 7, E. O., alcohol diet	99	2, 230	−12. 0	−14. 3	2, 434	2, 394	....	2, 394
GROUP H.								
No. 5, E. O., ordinary diet	109	2, 384	− 4. 2	− 7. 8	2, 482	2, 379	....	2, 379
No. 15, E. O., alcohol diet	104	2, 426	+ 6. 0	+ 3. 8	2, 357	2, 362	....	2, 362
No. 16, E. O., alcohol diet	104	2, 424	+ 7. 2	+ 5. 0	2, 336	2, 332	....	2, 332
No. 17, E. O., alcohol diet	104	2, 427	+ 6. 0	+11. 0	2, 289	2, 276	....	2, 276
Average 15, 16, 17	104	2, 426	+ 6. 4	+ 6. 6	2, 327	2, 323	....	2, 323
GROUP I.								
No. 21, A. W. S., ordinary diet	90	2, 038	− 5. 6	−24. 9	2, 304	2, 279	....	2, 279
No. 18, A. W. S., alcohol diet	90	2, 532	−12. 2	+25. 1	2, 367	2, 488	....	2, 488
No. 19, A. W. S., alcohol diet	90	2, 550	. 0	+35. 1	2, 220	2, 279	....	2, 279
No. 20, A. W. S., alcohol diet	90	2, 549	+ 2. 2	+21. 1	2, 339	2, 303	....	2, 303
Average 18, 19, 20	90	2, 544	− 3. 3	+27. 1	2, 309	2, 357	....	2, 357
GROUPS G, H, AND I.								
Average 13–14, 5, 21, ordinary diet	100	2, 239	− 7. 3	− 2. 3	2, 302	2, 277	....	2, 277
Average 7, 15 to 17, 18 to 20, alcohol diet	98	2, 400	− 3. 0	+ 6. 5	2, 356	2, 358	....	2, 358
GROUPS A TO I.								
Average 9, 24, 26–28, 11, 29–31, 32–34, 13–14, 5, 21, ordinary diet	102	2, 691	− 4. 8	− . 1	2, 717	2, 650	73	2, 723
Average 10, 22, 27, 12, 30, 33, 7, 15 to 17, 18 to 20, alcohol diet	102	2, 750	− 7. 1	+ 3. 8	2, 746	2, 680	72	2, 752

PROPORTIONS OF ALCOHOL OXIDIZED AND UNOXIDIZED.

In the experiments in which alcohol formed part of the diet the urine, drip, and freezer waters and outgoing air current were examined for the presence of alcohol, or the products of incomplete oxidation of alcohol, according to the method discussed on page 258. The determinations were made by the amount of reduction of a standard sulphuric-acid solution of chromic acid. The materials thus found were called reducing materials, and the total amounts were calculated as alcohol.

In 6 of the later experiments in which alcohol did not form part of the diet the same tests were made in the excretory and respiratory products as indicated above, and considerable quantities of reducing material were found. These were likewise calculated as alcohol. The average daily amount eliminated in each of these experiments and the average of the results of all 6 are shown in Table CXXI.

TABLE CXXI.—*Average daily elimination of reducing material by lungs and kidneys in experiments in which alcohol did not form a part of the diet.*

[Quantities expressed in alcohol equivalent.]

Experiment No.	Reducing material excreted, calculated as alcohol.		
	In urine.	In respiratory products.	Total.
	Grams.	*Grams.*	*Grams.*
26	0.02	0.36	0.38
28	.02	.24	.26
29	.01	.35	.36
31	.02	.28	.30
32	.02	.32	.34
34	.03	.28	.31
Average of all	.02	.30	.32

In the average of all 6 experiments the reducing material determined was found equivalent to 0.32 of a gram of alcohol per day. Accordingly, from the total amount of reducing material determined in the alcohol experiments, 0.3 gram was subtracted in estimating the amount of alcohol excreted unoxidized. This is shown in Table CXXII, which summarizes the data for the excretion of unoxidized alcohol in the different experiments. The figures in column *d* show the total amount of reducing material, calculated as alcohol, which was found in the distillates from the urine and the water condensed in the chamber and the freezers, and more especially in the air current. From each of the values in column *d* 0.3 gram is subtracted, as explained above, to obtain the values in column *e*, which represent the amount of alcohol excreted unoxidized. The difference between the alcohol ingested, column *a*, and that excreted, column *e*, represents the amount actually metabolized, column *f*. The latter amount divided by the amount ingested shows the per cent metabolized, column *g*.

It will be noticed that the values for alcohol metabolized in the body in experiments 7 to 22 are slightly larger in Table CXXII than they are in the tables giving the details of these experiments on preceding pages. This is due to the fact that in the detail tables the total amount of reducing material, as found in the experiments, was taken as the measure of the alcohol excreted in the experiments specified, whereas in the summary table the average amount of reducing material found has been deducted from the total reducing material in all the experiments alike.

TABLE CXXII.—*Comparison of amounts of alcohol consumed and excreted unoxidized in experiments in which it formed a part of the diet.*

Experiment No.	(a) Alcohol ingested.	Alcohol excreted, including other material calculated as alcohol. (b) In urine.	(c) In respiratory products.	(d) Total outgo, b+c.	(e) Alcohol excreted unoxidized. d−0.3.	Alcohol actually metabolized. (f) a−e.	(g) f÷a.
	Grams.	*Grams.*	*Grams.*	*Grams.*	*Grams.*	*Grams.*	*Per cent.*
7	72.5	0.22	2.76	2.98	2.7	69.8	96.3
10	72.5	.12	.98	1.10	.8	71.7	98.9
12	72.4	.15	1.34	1.49	1.2	71.2	98.3
15	72.5	.14	1.40	1.54	1.2	71.3	98.3
16	72.5	.19	1.90	2.09	1.8	70.7	97.5
17	72.5	.06	1.43	1.49	1.2	71.3	98.3
18	72.5	.14	1.83	1.97	1.7	70.8	97.7
19	72.5	.12	1.42	1.54	1.2	71.3	98.3
20	72.5	.14	1.69	1.83	1.5	71.0	97.9
22	72.0	.53	1.67	2.19	1.9	70.1	97.4
27	72.0	.11	1.09	1.20	.9	71.1	98.7
30	72.0	.06	1.03	1.09	.8	71.2	98.9
33	72.0	.05	1.00	1.05	.7	71.3	99.0
Average of all							98.1
Average of Nos. 27–33							98.9

VARIATIONS IN DAILY EXCRETION OF NITROGEN.

In the course of these experiments it has been found very difficult to obtain a uniform excretion of nitrogen in the urine from day to day, even with uniform conditions of food, rest, and work. In studying the effect of alcohol upon nitrogen metabolism these variations should be considered. Table CXXIII shows the daily nitrogen content in the urine in experiments with and without alcohol. It also shows the elimination of nitrogen on the days of the preliminary period which always preceded an experiment in the calorimeter, and during which the subject had very nearly the same diet as in the following experimental period. In many cases the amount of nitrogen in the urine varied greatly from day to day, this variation being especially marked in the preliminary period. This may possibly be due in part to differences in amounts of external muscular work performed on different days, but the general results of experiments on the effects of muscular activity upon nitrogen metabolism imply that when the work is not severe and the supply of energy is sufficient the output of nitrogen is not greatly increased. It seems more probable that the cause may be in part psychic. We have had occasion to note an increase of nitrogen excretion after mental excitement, and not infrequently such increase has occurred on the day before or the day after the subject entered the respiration chamber for an experiment. This was especially the case with E. O., with whom there was a notable increase in the excretion of nitrogen on the day before entering the chamber in experiments 5, 6, 7, 12, 13, and 14, and on the day after in experiments 10, 11, 15, and 22. Something of the same kind appears with A. W. S. in experiment 18, with the exception that the increase was observed on the second day of the preliminary period, continued for a few days, and, with the exception of a slight rise on the day after entering the calorimeter, greatly decreased in amount during experiments 18 to 20. With J. F. S., on the other hand, there was as a rule comparatively little difference in the nitrogen eliminated on different days of the preliminary period, and a very slight, although regular, increase on the day following his entrance into the calorimeter.

The figures in the last four columns of the table show the average elimination of nitrogen during different periods with and without alcohol as part of the diet. The pronounced difference in some experiments between the elimination of nitrogen in the preliminary period and the calorimeter period is of interest as indicating that these unexplained variations are much greater than any which may be brought about by the addition of alcohol to the diet. This is one of the facts which lead us to hesitate to attribute to the alcohol any definite and uniform effect upon the metabolism of nitrogen.

One thing has impressed us, not only in these experiments but in others, the results of which we have studied. It is that the daily nitrogen balance is a much less reliable indication of the effects of diet, or of drugs, or of muscular work, or of medical treatment than is commonly supposed.[a]

TABLE CXXIII.—*Comparison of daily elimination of nitrogen in the urine when alcohol did and did not form a part of the diet.*

[Figures in bold face indicate days in which alcohol formed a part of the diet.]

Experiment and subject.	Nitrogen in food.	Nitrogen in urine, preliminary period. First day.	Second day.	Third day.	Fourth day.	Nitrogen in urine, calorimeter period. First day.	Second day.	Third day.	Fourth day.	Fifth day.	Sixth day.	Seventh day.	Eighth day.	Ninth day.	Nitrogen in urine, average. Preliminary period.	Calorimeter period. Total period.	With ordinary diet.	With alcohol.
E. O.	Gms.	Gms.	Gms.	Gms.	Gms.	Gms.	Gms.	Gms.	Gms.	Gms.	Gms.	Gms.	Gms.	Gms.	Gms.	Gms.	Gms.	Gms.
Experiment Nos. 13 and 14	16.9	15.3	16.0	17.2	20.2	20.2	17.4	16.9	16.5	....	....	....	....	....	17.2	17.8	17.7	....
Experiment No. 7	**16.7**	....	**19.1**	**15.9**	**18.5**	**19.6**	**17.8**	**16.2**	**17.3**	....	....	....	....	....	**17.8**	**17.7**	....	**17.7**
Experiment No. 9	19.1	17.4	22.1	20.1	17.9	18.7	18.8	18.3	17.9	....	....	....	....	....	19.4	18.4	18.4	....
Experiment No. 10	**19.8**	**17.6**	**20.5**	**12.3**	**14.2**	**19.7**	**20.6**	**19.4**	**18.1**	....	....	....	....	....	**16.2**	**19.5**	....	**19.5**
Experiment No. 11	19.9	12.5	11.7	13.6	13.8	17.5	17.1	18.3	19.4	....	....	....	....	....	12.9	18.1	18.1	....
Experiment No. 12	**19.3**	**10.1**	**15.4**	**13.8**	**18.3**	**17.9**	**21.3**	**15.9**	**17.7**	....	....	....	....	....	**14.4**	**18.2**	....	**18.2**
Experiment No. 5	19.1	17.2	17.6	14.2	23.8	20.3	17.4	17.2	17.4	....	....	....	....	....	18.2	18.1	18.1	....
Experiment Nos. 15–17	**17.4**	**11.6**	**16.0**	**13.9**	**10.4**	**15.1**	**16.2**	**15.2**	**15.7**	**15.7**	**15.6**	....	....	....	**13.0**	**15.6**	....	**15.6**
Average 13 and 14, 9, 11, 5	18.8	15.6	16.9	16.3	18.9	19.2	17.7	17.7	17.8	....	....	....	....	....	16.9	18.1	18.1	....
Average 7, 10, 12, 15–17	**18.3**	**13.1**	**17.8**	**14.0**	**15.4**	**18.1**	**19.0**	**16.7**	**17.2**	....	....	....	....	....	**15.4**	**17.7**	....	**17.8**
Experiment Nos. 22–24	19.8	17.3	18.8	14.6	**13.7**	**18.7**	**18.8**	**17.8**	18.8	19.6	18.5	19.4	18.1	17.3	16.1	18.5	18.6	**18.4**
A. W. S.																		
Experiment Nos. 4a–4c	15.3	15.0	15.6	14.3	14.4	14.6	14.1	13.1	13.7	12.6	11.9	12.4	13.1	11.7	14.8	13.0	13.0	....
Experiment Nos. 18–21	**15.5**	**12.2**	**16.0**	**19.0**	**16.4**	**17.4**	**15.4**	**14.7**	**14.2**	**13.8**	**14.4**	14.5	16.2	15.4	**15.9**	15.0	15.4	**15.0**
J. F. S.																		
Experiment Nos. 26–28	15.9	16.6	15.9	15.7	16.0	16.6	15.1	14.4	**14.6**	**15.5**	**16.8**	15.9	15.2	14.7	16.0	15.4	15.3	**15.6**
Experiment Nos. 29–31	16.0	13.9	15.5	15.0	14.8	15.4	16.3	16.2	**16.8**	**18.0**	**17.1**	16.3	15.4	15.2	14.8	16.3	15.8	**17.3**
Experiment Nos. 32–34	16.1	15.0	15.5	15.6	15.1	16.3	15.3	15.6	**16.7**	**17.6**	**17.7**	17.4	16.3	16.4	15.3	16.6	16.2	**17.3**
Average 26–34	16.0	15.2	15.6	15.4	15.3	16.1	15.6	15.4	**16.0**	**17.0**	**17.2**	16.5	15.6	15.4	15.4	16.1	15.8	**16.7**

[a] My own confidence in the results of the experiments of a few days' duration as indications of the influence of any such agencies upon nitrogen metabolism was much shaken by the experience of Dr. C. F. LANGWORTHY and myself in collating and comparing the results of experiments on these subjects in the course of the preparation by ourselves of Bulletin 45 of the Office of Experiment Stations of the United States Department of Agriculture, A Digest of Metabolism Experiments in which the Balance of Income and Outgo was observed. The tables of this volume include summaries of 2,299 experiments with men and 1,362 with animals, in which the nitrogen balance was studied. The very clear impression left upon my own mind is that a not inconsiderable share of the conclusions reached by the authors of this very large amount of painstaking inquiry must be held subject to revision in the light of inquiries in which the experimental periods will be longer and the determinations more detailed.—W. O. A.

AVAILABILITY OF NUTRIENTS AND ENERGY.

Table CXXIV compares the coefficients of availability of protein, fat, carbohydrates, and energy in experiments in which alcohol did and did not form a part of the diet. These experiments are compared according as the ordinary diet and alcohol diet were more or less comparable, and according to the character of the experiment, whether rest or work.

TABLE CXXIV.—*Coefficients of availability of nutrients and energy in diet with and without alcohol.*

Metabolism experiment No.	Digestion experiment No.	Classification, serial numbers, and subjects of experiments.	Duration.	Protein.	Fat.	Carbohydrates.	Alcohol.	Energy.
		Experiments with and without alcohol more strictly comparable.						
		REST EXPERIMENTS.						
		GROUP A.	Days.	Per ct.	Per ct.	Per ct.	Per ct.	Per ct.
9	46	E. O., ordinary diet	4	93.5	93.9	96.5	......	89.7
10	48	E. O., alcohol diet	4	93.1	88.2	97.0	98.5	89.8
		GROUP B.						
24	85	E. O., ordinary diet	3	93.2	93.7	98.9	......	91.6
22	83	E. O., alcohol diet	3	94.4	94.7	97.9	96.9	90.5
		GROUPS A AND B.						
		Average Nos. 9, 24, ordinary diet	7	93.4	93.8	97.7	......	90.7
		Average Nos. 10, 22., alcohol diet	7	93.8	91.5	97.5	97.7	90.2
		GROUP C.						
26	150	J. F. S., ordinary diet	3	93.1	97.2	97.3	......	91.1
28	152	J. F. S., ordinary diet	3	92.2	90.1	98.6	......	91.1
		Average Nos. 26, 28	6	92.7	93.7	98.0	......	91.1
27	151	J. F. S., alcohol diet	3	92.8	95.0	97.2	98.7	91.4
		GROUPS A TO C.						
		Average Nos. 9, 24, 26–28, ordinary diet	13	93.1	93.8	97.8	......	90.8
		Average Nos. 10, 22, 27, alcohol diet	10	93.4	92.6	97.4	98.0	90.6
		WORK EXPERIMENTS.						
		GROUP D.						
11	50	E. O., ordinary diet	4	88.7	93.0	97.5	......	90.9
12	52	E. O., alcohol diet	4	93.5	95.9	98.2	97.9	92.7
		GROUP E.						
29	154	J. F. S., ordinary diet	3	94.6	97.2	98.7	......	94.1
31	156	J. F. S., ordinary diet	3	95.0	98.3	98.2	......	94.1
		Average Nos. 29, 31	6	94.8	97.8	98.5	......	94.1
30	155	J. F. S., alcohol diet	3	95.8	98.1	98.6	98.9	94.5
		GROUP F.						
32	158	J. F. S., ordinary diet	3	92.8	97.1	97.4	......	92.7
34	160	J. F. S., ordinary diet	3	92.7	95.0	98.4	......	93.2
		Average Nos. 32, 34	6	92.8	96.2	97.9	......	93.0
33	159	J. F. S., alcohol diet	3	92.7	95.6	97.8	99.0	93.1
		GROUPS E AND F.						
		Average Nos. 29, 31, 32, 34, ordinary diet	12	93.8	96.9	98.2	......	93.5
		Average Nos. 30, 33, alcohol diet	6	94.3	96.9	98.2	99.0	93.8
		GROUPS D TO F.						
		Average 11, 29–31, 32–34, ordinary diet	16	92.1	95.7	98.0	......	92.7
		Average 12, 30, 33, alcohol diet	10	94.0	96.5	98.2	98.6	93.4
		GROUPS A TO F.						
		Average Nos. 9, 11, 24, 26–28, 29–31, 32–34, ordinary diet	29	92.6	94.9	97.9	......	91.9
		Average Nos. 10, 12, 22, 27, 30, 33, alcohol diet	20	93.7	94.6	97.8	98.3	92.0

TABLE CXXIV.—*Coefficients of availability of nutrients and energy in diet with and without alcohol*—Continued.

Metabolism experiment No.	Digestion experiment No.	Classification, serial numbers, and subjects of experiments.	Duration.	Protein.	Fat.	Carbohydrates.	Alcohol.	Energy.
		Experiments with and without alcohol less strictly comparable.						
		REST EXPERIMENTS.						
		GROUP G.	*Days.*	*Per ct.*	*Per ct.*	*Per ct.*	*Per ct.*	*Per ct.*
13	77	E. O., ordinary diet	3	94.0	93.2	98.1	......	90.0
14	79	E. O., ordinary diet	4	93.8	95.3	98.7	......	91.9
		Average Nos. 13, 14	7	93.9	94.3	98.4	......	91.0
7	42	E. O., alcohol diet	4	94.8	96.3	98.1	95.9	91.1
		GROUP H.						
5	38	E. O., ordinary diet	4	91.3	93.9	97.7	......	89.6
15–17	81	E. O., alcohol diet	6	95.2	92.5	98.4	97.6	91.5
		GROUPS G AND H.						
		Average Nos. 13+14, 5, ordinary diet	11	92.6	94.1	98.1	......	90.3
		Average Nos. 7, 15–17, alcohol diet	10	95.0	94.4	98.3	96.8	91.3
		GROUPS A TO H.						
		Average all experiments with ordinary diet, Nos. 9+24, 26−28, 11, 29+31, 32+34, 13+14, 5	40	92.6	94.7	98.0	......	91.5
		Average all experiments with alcohol diet, Nos. 10+22, 27, 12, 30+33, 7, 15–17	30	94.1	94.7	97.9	97.8	91.8

Table CXXV summarizes the results of experiments with the same subject and the same diet before and after entering the calorimeter and averages the results for all the experiments.

TABLE CXXV.—*Comparison of gains or losses of nitrogen, and of coefficients of availability in the preliminary periods outside the calorimeter and the experimental periods inside.*

[Quantities per day.]

Metabolism experiment No.	Digest experiment No.		Duration.	Nitrogen. In food.	Nitrogen. In feces.	Nitrogen. In urine.	Nitrogen. Gain (+) or loss (−).	Coefficients of availability. Protein.	Coefficients of availability. Fat.	Coefficients of availability. Carbohydrates.	Coefficients of availability. Alcohol.	Coefficients of availability. Energy.
		Experiments with ordinary diet.										
		REST EXPERIMENTS.	*Days.*	*Grams.*	*Grams.*	*Grams.*	*Grams.*	*Per ct.*	*Per ct.*	*Per ct.*	*Per ct.*	*Per ct.*
5	37	Preliminary period	4	19.2	1.4	18.2	−0.4	92.7	94.0	98.0	......	90.0
	38	Calorimeter period	4	19.1	1.7	18.1	−0.7	91.3	93.9	97.7	......	89.6
8	43	Preliminary period	4	20.1	1.8	14.2	+4.1	91.3	94.4	97.4	......	89.9
	44	Calorimeter period	4	20.8	1.3	19.5	......	94.0	95.6	98.2	......	90.8
9	45	Preliminary period	4	18.9	1.7	19.4	−2.2	90.9	92.1	95.8	......	88.5
	46	Calorimeter period	4	19.1	1.3	18.4	−0.6	93.5	93.9	96.5	......	89.7
13	76	Preliminary period	4	20.1	0.8	18.1	+1.2	96.7	96.3	98.9	......	93.1
	77	Calorimeter period	3	18.7	1.1	19.5	−1.9	94.0	93.2	98.1	......	90.0
14	78	Preliminary period	3	15.1	1.2	16.7	−2.8	92.3	93.4	98.5	......	91.1
	79	Calorimeter period	4	15.1	0.9	16.2	−2.0	93.8	95.3	98.7	......	91.9
25	147	Preliminary period	4	17.6	1.0	16.6	......	94.2	96.8	97.7	......	91.8
	148	Calorimeter period	3	17.7	1.0	16.4	+0.3	94.5	97.4	97.4	......	91.8
26	149	Preliminary period	4	15.9	1.7	16.0	−1.8	89.0	94.1	95.7	......	88.4
	150	Calorimeter period	3	15.9	1.1	15.4	−0.6	93.1	97.2	97.3	......	91.1
		Average preliminary periods		18.1	1.4	17.0	−0.3	92.4	94.4	97.4	......	90.4
		Average calorimeter periods		18.1	1.2	17.7	−0.8	93.5	95.2	97.7	......	90.7
		Work experiments.										
6	39	Preliminary period	4	19.1	1.9	12.8	+4.4	90.1	95.3	97.6	......	91.2
	40	Calorimeter period	4	19.1	1.5	16.5	+1.1	92.0	96.9	98.3	......	92.6
11	49	Preliminary period	4	19.9	1.9	12.9	+5.1	90.6	93.2	97.8	......	91.4
	50	Calorimeter period	4	19.8	2.2	18.1	−0.5	88.7	93.0	97.5	......	90.9
29	153	Preliminary period	4	15.9	0.9	14.8	+0.2	94.5	96.4	98.7	......	93.8
	154	Calorimeter period	3	16.0	0.8	16.0	−0.8	94.6	97.2	98.7	......	94.1
32	157	Preliminary period	4	15.9	1.5	15.0	−0.6	90.6	95.7	96.8	......	91.5
	158	Calorimeter period	3	16.1	1.2	15.7	−0.8	92.8	97.1	97.4	......	92.7
		Average preliminary periods		17.7	1.5	13.9	+2.3	91.5	95.2	97.7	......	92.0
		Average calorimeter periods		17.7	1.4	16.6	−0.3	92.0	96.1	98.0	......	92.6

TABLE CXXV.—*Comparison of gains or losses of nitrogen, and coefficients of availability in the preliminary periods outside the calorimeter and the experimental periods inside*—Continued.

Metabolism experiment No.	Digest experiment No.		Duration.	Nitrogen. In food.	Nitrogen. In feces.	Nitrogen. In urine.	Nitrogen. Gain (+) or loss (−).	Coefficients of availability. Protein.	Coefficients of availability. Fat.	Coefficients of availability. Carbohydrates.	Coefficients of availability. Alcohol.	Coefficients of availability. Energy.
		Experiments with alcohol diet.										
		REST EXPERIMENTS.										
			Days.	*Grams.*	*Grams.*	*Grams.*	*Grams.*	*Per ct.*	*Per ct.*	*Per ct.*	*Per ct.*	*Per ct.*
7	41	Preliminary period	5	16.8	1.5	17.8	−2.5	90.8	93.6	97.3	95.9	89.2
	42	Calorimeter period	4	16.7	0.9	17.7	−1.9	94.8	96.3	98.1	95.9	91.1
10	47	Preliminary period	4	19.5	1.0	16.1	+2.4	94.9	92.1	98.0	98.5	91.1
	48	Calorimeter period	4	19.8	1.4	19.5	−1.1	93.1	88.2	97.0	98.5	89.8
15	80	Preliminary period	4	16.7	0.8	13.0	+2.9	95.2	91.8	98.0	97.6	91.4
	81	Calorimeter period	2	17.4	0.8	15.6	+1.0	95.2	92.5	98.4	97.6	91.5
22	83	Preliminary period	4	19.7	1.2	16.1	+2.4	94.2	94.5	98.2	97.0	90.5
	84	Calorimeter period	3	19.8	1.1	18.4	+0.3	94.4	94.7	97.9	97.0	90.5
		Average preliminary periods	......	18.2	1.1	15.8	+1.3	93.8	93.0	97.9	97.2	90.6
		Average calorimeter periods	......	18.4	1.0	17.8	−0.4	94.4	92.9	97.9	97.2	90.7
		Work experiments.										
12	51	Preliminary period	4	19.6	1.8	14.4	+3.4	90.8	94.2	97.0	97.9	91.3
	52	Calorimeter period	4	19.3	1.3	18.2	−0.2	93.5	95.9	98.2	97.9	92.7
		Average preliminary periods in all above experiments with ordinary diet	......	18.0	1.4	15.9	+0.7	92.1	94.7	97.5	......	91.0
		Average calorimeter periods in all above experiments with ordinary diet	......	17.9	1.3	17.3	−0.6	92.9	95.5	97.8	......	91.4
		Average preliminary periods in all above experiments with alcohol diet	......	18.5	1.[illegible]	15.5	+1.7	93.2	93.2	97.7	97.4	90.7
		Average calorimeter periods in all above experiments with alcohol diet	......	18.6	1.1	17.8	−0.3	94.2	93.5	97.9	97.4	91.1

The figures for the availability of alcohol in the preliminary period are based upon the assumption that the excretion of unoxidized alcohol was the same during the preliminary period as during the following period when the subject was within the chamber of the respiration calorimeter. It will be observed that while the diet was practically the same in the preliminary as in the calorimeter period, the coefficients of availability are quite different. Sometimes the subject appeared to digest the food more thoroughly during the preliminary period and sometimes more thoroughly during the period spent within the respiration chamber. In both the rest and work experiments without alcohol the availability of the nutrients and energy of the diet was slightly less in the preliminary period than in the subsequent experiment in which the subject was within the respiration chamber. In the rest experiments in which alcohol formed a part of the diet there was no pronounced difference in the coefficients in the two cases, but in the one instance in which there was preliminary and calorimeter period with work the coefficients of availability in the former period were noticeably less than in the latter.

Taking all the experiments into consideration it would seem that there was, as a rule, a quite noticeable difference in the proportions of the food which were actually made available for use in the body in the preliminary as compared with the calorimeter periods, a difference which was not noticeably affected by the presence or absence of alcohol in the diet.