A STUDY OF WEIGHT REGULATION IN THE ADULT HUMAN BODY DURING OVER-NUTRITION

ADDISON GULICK

From the Laboratory of Physiological Chemistry, Department of Physiology
University of Missouri, Columbia

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In contrast to the brilliant successes that science has won in the study of nitrogen equilibrium, there is a rather discouraging inconclusiveness in the work that has been done on the factors that regulate the nutritive balance of the fat tissue of the body, and the balance between the total intake and total output of potential and kinetic energy in the adult warm-blooded organism. We do not yet know what mechanism there is to prevent the unlimited accumulation of potential energy in the form of an overload of adipose tissue. Is nerve regulation through changing appetite the only guide, or does the body vary its destruction of fats and carbohydrates in accordance with their fluctuating intake, somewhat after the manner that it varies its nitrogen exchange?

The best road to a true solution is probably in a study of selected contrasting individuals of the over-fat and under-fat body habits, or better still, of the easily fattening and difficultly fattening types.

The problem was first drawn to my attention by observation of myself, and the experiments here reported were performed upon myself as a selected example of the “spare” or apparently non-fattening type. I had long noted my inclination toward a very copious diet of predominantly starchy nature, in spite of which my weight remained fairly constant, even on a moderate round of activity, at a figure well below the average for my stature. If the hereditary constitution is important in this connection, such family data as I possess seem to indicate that I am derived largely from non-fattening strains.

It has long been recognized that food intake has a powerful effect on the rate of oxidation in the body. In the case of protein food, Rubner (1) distinguishes two such effects. The first of these is the oft discussed specific dynamic effect. The second is a change which appears
more gradually, and is explained by him as a stimulus from plethora of nitrogenous products in the cell fluids. The specific dynamic effect occurs equally in well-fed and badly-fed animals, and so it cannot function as a safety valve for excessive intake. But the secondary or plethora effect may very well so function. According to Rubner, this effect shows itself as a cumulative increase in the specific dynamic effect of heavy protein meals, when they are administered on a series of days. He states that in spite of its cumulative character, this secondary effect is not in evidence during the hours when no food is being absorbed. Consequently a dog that has been over-fed in this manner shows no change in its basal metabolic rate, as ordinarily determined on an empty stomach (p. 260, loc. cit.).

Similar results are reported by Dengler and Meyer (2) in their study of the basal metabolism of a man who was over-fed with protein. They found the basal rate changed to a surprisingly slight degree as a result of nitrogen accumulation, and hence conclude that the excess of stored nitrogen was in a non-stimulating form.

A. Müller (3), in tests on a young man, found that the secondary rise on a high protein diet develops rapidly, before much nitrogen storage can have occurred, and then fails to keep pace with the stored nitrogen, and is at best trivial in proportion to the quantity of nitrogen that is finally accumulated. So he does not look upon this heightened catabolism as a result of the stored nitrogen.

Grafe and Koch (4) experimented upon persons who entered a clinic in an extremely under-nourished condition. The two principal subjects were both put through a heavy feeding period of 7 weeks' duration to bring them back to normal weight. There resulted a very notable increase in the gaseous exchange. Thus the adult subject, at the initial weight of 40.3 kgm., showed a basal metabolism of 1081 cal. (26.8 cal. per kgm.) and a dynamic effect from eating a meal equal to 24 per cent of the calorie value of the meal. Seven weeks later at a weight of 60 kgm., the basal metabolism had risen to 1946 cal., (32.3 cal. per kgm.) and the dynamic effect had risen to 32 per cent of the fuel value of the meal. Most of the gain in basal metabolism occurred near the middle of the experiment. Although it appeared less rapidly than in Müller's experiment, it was of greater magnitude. The tests of the dynamic effect of the mixed diet fluctuated widely, and cannot be easily interpreted.

Atkinson and Lusk (5) experimented along lines similar to those followed by Rubner, but by over-feeding to a greater extreme were
able to report that prolonged and excessive meat diet can cause a rise of the dog's basal metabolism which lasts for as much as two and one-half weeks after the special diet is ended. For their case, then, they conclude that the excess nitrogen was accumulated in a stimulating form.

The converse to the idea of increased or spendthrift oxidation during over-nourishment, is the idea of an especially economical oxidation during under-nutrition.

Anderson and Lusk (6) studied the respiration and the treadmill efficiency of a dog working with empty stomach, with definite meals, and during a prolonged fast. Among other things it was found that the markedly lowered basal metabolism of the fasting period, with its economy of nourishment, carried over into the period immediately following the fast. Eighteen hours after the first liberal meal the metabolism was at essentially the same base level as during the fast, showing that the total condition of the body, and not the question of a large or small influx of food on the previous day, determined the height of the basal metabolism. It is thus to be noted that this dog showed a persistent economy of metabolism after a period of fasting, comparable to the period of wasteful metabolism which Atkinson and Lusk's dog showed subsequent to a course of over-feeding.

The period of the World War has brought out a series of papers on gaseous metabolism during prolonged under-nutrition. Zuntz and Loewy (7), (8), who have a series of records of their basal metabolism since 1888, studied the effect on themselves of eating the German war ration, practically without any of the additions that free use of money could furnish. On this diet, which was inadequate in fuel value, and especially deficient in protein, they report in the case of Zuntz a 10 per cent fall of basal metabolism below the previous average, and in the case of Loewy a fall of 16 per cent. This decrease is reported in terms of calories per day per square meter by the Meeh formula. The more accurate DuBois formula would show even greater percentage changes in rate. Muscular efficiency on the treadmill had gone down in comparison to previous tests.

F. G. Benedict, Miles, Roth and Smith (9) worked on the metabolism of volunteer squads of young men during experimental under-nutrition which covered three months of low diet. They found a very remarkable fall in the total fuel needs. Starting at an unknown high level which was above 3000 cal., and may have been as high as 3800 cal., they were finally able to hold their weight constant on an average net intake per
person of 1950 cal., the fecal and urinary calories being estimated and deducted. Meanwhile there had been a notable loss of nitrogen, 130 grams previous to the first serious interruption (at Christmas) and further losses to the end of the experiment. The basal metabolism fell from an average of 1886 cal. at the start to 1367 cal. at the lowest point, or from 940 per sq. m. to 788 per sq. m. Thus the absolute figures fell 20 per cent and the rate per square meter came down 16 per cent. A remarkable slowing of the pulse accompanied this change. Efficiency in the tests of mechanical work was not impaired. The authors ascribe the changes to the withdrawal of the influence of dispensable nitrogen from the body, and argue that no great inroads had been made on the essential protoplasm.

Joffe, Poulton and Ryffel (10) report upon a case of extreme undernutrition in a vegetarian, who had probably previously habituated himself to a very meager intake. Throughout the tests the basal rate stayed in the neighborhood of 26.6 cal. per square meter per hour, or 638 per square meter per day, calculated according to DuBois. The increment of oxidation during work was about average, showing that the man had about the average of caloric efficiency in work. His pulse was always below 50 in the reclining position.

Investigators agree, then, that when the diet is varied downward there is a factor or group of factors tending to adjust the calorie output to the intake.

All the researches thus far reviewed follow the method of gas analysis, and judge the balance between intake and output so far as possible by a direct measurement of both. Another plan of procedure is to depend upon the body weight as the criterion to show whether a balance of intake and output has been established. In order to obtain convincing results by this plan it is necessary to let the tests cover long periods of time, and also to have very large differences in the measured diets of the different experimental periods, so as to far outweigh any variations in energy expenditure that may come from uncontrolled factors. In the past this general mode of experiment has been used, either with or without a supplementary study of the gas metabolism, chiefly by Neumann and by Grafe and his pupils.

Neumann (11) carried out upon himself one of the most prolonged quantitative diet experiments ever recorded, and showed a food intake which gave averages on different years of 2427 cal. and 2057 cal. respectively per 70 kgm. body weight. The actual weight in the former test (1895–96) averaged 66.5 kgm., and in the latter test (1900–01)
averaged 72 kgm. In both years the weights were virtually stationary, tending slightly upward. Neumann's results seem to show ability of the organism to stabilize its weight on either low or medium intakes of fuel. But they do not deal in extreme differences of diet.

Grafe and Graham (12) carried out a prolonged experiment upon a dog, keeping full account of the nitrogen metabolism and weight during very marked over-feeding. From time to time the gas exchange was also determined. Although prevented from taking much exercise, this dog showed extraordinary constancy of body weight during both normal diet and excessive feeding. A puzzling feature is the fairly moderate gas exchange which the dog showed in all the tests.

It might be hoped that comparison of the metabolism in abnormally obese individuals and in persons of normal body habit might throw some light on the factors that prevent most persons from fattening indefinitely. This aspect of the problem was studied by Rubner (13), by A. Magnus-Levy (14) and by von Noorden (15). As summarized by von Noorden, the weight of evidence in these earlier papers is for a fairly comparable metabolic rate in these and the normal cases. DuBois and his colleagues improved this observation by applying new methods for determining the surface area of the human body. (See James H. Means (16), and F. C. Gebhart and Eugene F. DuBois (17).) Using DuBois' determinations of surface, it is easily shown that the great majority of over-fat subjects have a basal rate falling well within the normal rate per square meter of surface. This establishes the fact that the laying on of fat is not caused by a depression in the basal rate. The alternatives still left to account for an obese human type are (a) an unproved possibility, referred to by von Noorden, that without having a lowered basal rate, the obese may still show an exceptionally low cost of digestion, perhaps by not showing the full normal specific dynamic effect of foods; or (b) that they partially or entirely lack Rubner's "secondary effect," which causes an upward shoving of the specific dynamic effect, and sometimes even of basal metabolism, whenever the protein over-nutrition becomes cumulative; or (c) that control over fattening is not referable to any alteration of basal metabolism nor of the energy cost of digestion, but is to be sought in some such factor as a changed appetite.

We may sum up from the literature that under-nutrition (with loss of nitrogen) has a marked lowering effect on the basal metabolic rate and on the total metabolism of the twenty-four hours. Over-nutrition, coupled with heavy enrichment of the body with nitrogen, has at
least in some instances an effect on the basal rate, and has been repeatedly found by Rubner and others to push up the specific dynamic or stimulating effect of protein during absorption, to higher and higher figures. Whenever these factors are at work they all tend to limit the fluctuation of the body mass, and especially to limit the accumulation of body protein. Grafe and his collaborators are the only ones who have argued that a similar type of factors is powerful in preventing the immoderate accumulation of body fat.

**OUTLINE OF EXPERIMENTS.** The general intention of the experiments here reported was to attempt to establish constancy of weight at various levels of total intake. In order to insure the adequacy of the protein and accessories throughout the experiment, milk and eggs figure in all the dietaries used. Small amounts of fats were used but excesses were avoided because it is too easily conceivable that fats might be shunted into the adipose tissue, making a passive increase of body weight without in any way having shared in the metabolism. The main source of nourishment was carbohydrate, from rice, wheat and oats, and the experiments consisted chiefly in varying the quantity of starchy food from these sources.

The first test in March, April and May, 1916, was to find the minimum diet that would maintain an approximately normal body weight. After that the intention was to establish a constant weight on a high level of exchange. This attempt lasted with interruptions from May, 1916, to July, 1917.

At the height of this period of maximum weight and food intake the basal metabolism was determined by the analysis of gas exchange, conducted at the Carnegie Nutrition Laboratory, through the courtesy of Dr. F. G. Benedict and Dr. Thorne M. Carpenter. The body weight was then brought back rather abruptly to the initial level by means of a low calorie diet in July and August, 1917. To conclude the experiment another determination was made of the quantity of food necessary to hold the weight constant.

During several of the above periods records were made of general physical activity. Data were taken for the nitrogen balance during the period of rapid reduction. Analyses of foods were made for this period, but not for any of the other periods, nor were any tests made of combustion value. Instead the diet was limited to a very small selection of foods that would be as free as possible from erratic fluctuations in composition. This method is undoubtedly liable to a certain degree of inaccuracy, but not, we believe, to major errors.
### TABLE 1
Condensed outline of dietary

<table>
<thead>
<tr>
<th>EXPERIMENTAL PERIOD AND DATE</th>
<th>I</th>
<th>II</th>
<th>III and IV</th>
<th>V</th>
<th>VI</th>
</tr>
</thead>
<tbody>
<tr>
<td>1916 March 4 to 23</td>
<td>100</td>
<td>200</td>
<td>1450</td>
<td>50</td>
<td>Six to eight</td>
</tr>
<tr>
<td>Rolied oats, gram (air dry)</td>
<td>0</td>
<td>0</td>
<td>0</td>
<td>0</td>
<td>Two</td>
</tr>
<tr>
<td>Rice, gram (air dry)</td>
<td>300</td>
<td>300</td>
<td>300</td>
<td>325</td>
<td>Six to ten</td>
</tr>
<tr>
<td>Milk, cc</td>
<td>1450</td>
<td>1450</td>
<td>1450</td>
<td>1450</td>
<td>Six to eight</td>
</tr>
<tr>
<td>Butter, gram</td>
<td>30</td>
<td>30</td>
<td>35</td>
<td>50</td>
<td>Two</td>
</tr>
<tr>
<td>Rolls (40-50 grams each)</td>
<td>Two</td>
<td>Two</td>
<td>Two</td>
<td>Six to ten</td>
<td></td>
</tr>
<tr>
<td>Eggs (45-55 grams each)</td>
<td>Two</td>
<td>Two</td>
<td>Two</td>
<td>Two</td>
<td></td>
</tr>
<tr>
<td>Sugar, gram</td>
<td>0</td>
<td>0</td>
<td>0</td>
<td>30</td>
<td></td>
</tr>
</tbody>
</table>

---

<table>
<thead>
<tr>
<th>EXPERIMENTAL PERIOD AND DATE</th>
<th>VII</th>
<th>VIII</th>
<th>IX</th>
<th>X</th>
<th>XI to XIII</th>
</tr>
</thead>
<tbody>
<tr>
<td>1917 July 8-14</td>
<td>100</td>
<td>100</td>
<td>100</td>
<td>100</td>
<td>100</td>
</tr>
<tr>
<td>Rolied oats, grams (air dry)</td>
<td>200</td>
<td>96.4</td>
<td>60</td>
<td>95</td>
<td>200</td>
</tr>
<tr>
<td>Rice, grams (air dry)</td>
<td>1402.7</td>
<td>1541.9</td>
<td>1417.5</td>
<td>1402</td>
<td>1393</td>
</tr>
<tr>
<td>Milk, cc</td>
<td>40</td>
<td>0</td>
<td>0</td>
<td>0</td>
<td>0</td>
</tr>
<tr>
<td>Butter, grams (pure fat)</td>
<td>100.2</td>
<td>251.1</td>
<td>251.3</td>
<td>126.5</td>
<td>Two</td>
</tr>
<tr>
<td>Eggs (45-55 grams each)</td>
<td>375 gm.</td>
<td>6.8 gm.</td>
<td>0</td>
<td>0</td>
<td>One</td>
</tr>
<tr>
<td>Shredded wheat biscuit (about 30 grams each)</td>
<td>0</td>
<td>0</td>
<td>0</td>
<td>0</td>
<td>Two</td>
</tr>
</tbody>
</table>

- Diet irregular but essentially like Period VI (Respiratory analyses).
or large systematic discrepancies that would alter the tenor of the conclusions.

The figures for the calorie values of the foods are taken consistently from Atwater and Woods’ tables published by the U. S. Dept. of Agriculture (18). These figures are based on Rubner’s standard values for the physiologically available energy in protein, fat and carbohydrates when presented in the digestive tract in “perfectly digestible” form. Up to July, 1917, the foods were all of this “perfectly digestible” form, and it would be correct theoretically to use these fuel values without deducting for the loss by feces. After that date the use of shredded wheat in the diet caused a considerable increase in the moist weight of feces, but apparently not so great a change in the dry weight. The dry weight of a series of feces samples which were closely comparable to those of March and April, 1916 (ration of 2744 cal.), averaged 27 grams per day. This figure comes from an unreported preliminary test made in April, 1915. In June, 1916, it was about 51 grams per day (on 3800 calories), and in July, 1917, it was 78 grams (on 4113 calories with much shredded wheat). In August, 1917, it was about 22 grams (low diet), and in November about 35 grams (3200 calories with medium supply of shredded wheat).

The principal data obtained are the records of weight variation. Every effort was made to obtain reliable and comparable weighings. The regular hour was between 11:30 a.m. and 12:00 m. The fewest possible changes were made in the dietary of the breakfasts, in order to minimize the fluctuations that come from variation in the contents of the digestive tract. Defecation ordinarily occurred in the forenoon, and no weighings are included from the exceptional days on which it had not occurred before the hour for taking the weight. No laxative was used at any time. Care was taken that the bladder should be empty and that the stomach should not contain drinking water at the weighing hour. Whenever the weather was sultry, some water was drunk at about 9:30 to insure against shortage at 11:30. In spite of these precautions there were some rather disconcerting fluctuations of weight, that must be ascribed to variations of water metabolism. Some of the low weights that show abnormally low water content occurred in connection with temporary constipation, and were thus automatically excluded. In cases of insomnia (of which there were several instances toward the end of the experiments) there always resulted an abrupt transitory fall of weight, which is probably chiefly due to an accelerated renal activity. Some of these weights were
**TABLE 2**

Relation between food intake and body weight

<table>
<thead>
<tr>
<th>Period and Date</th>
<th>I 1916 March 4-29</th>
<th>II 1916 March 30 to May 9</th>
<th>III 1916 May 10-25</th>
<th>IV 1916 May 26 to June 12</th>
<th>V 1916 October 24 to December 12</th>
<th>VI 1917 March 24 to June 4</th>
<th>VII 1917 July 15 to September 1</th>
<th>VIII 1917 September 2 to October 12</th>
<th>IX 1917 October 23-27</th>
<th>X 1917 October 28 to November 10</th>
<th>XI 1917 November 11-25</th>
</tr>
</thead>
<tbody>
<tr>
<td>Duration in days</td>
<td>26</td>
<td>41</td>
<td>16</td>
<td>18</td>
<td>50</td>
<td>73</td>
<td>7</td>
<td>49</td>
<td>41</td>
<td>11</td>
<td>14</td>
</tr>
<tr>
<td>Initial weight</td>
<td>63.89</td>
<td>62.11</td>
<td>61.60</td>
<td>63.85</td>
<td>70.05</td>
<td>71.20</td>
<td>74.08</td>
<td>74.72</td>
<td>65.14</td>
<td>62.31</td>
<td>61.75</td>
</tr>
<tr>
<td>Average weight</td>
<td>62.90</td>
<td>61.80</td>
<td>62.76</td>
<td>64.89</td>
<td>70.78</td>
<td>71.81</td>
<td>74.28</td>
<td>68.90</td>
<td>63.75</td>
<td>61.94</td>
<td>61.88</td>
</tr>
<tr>
<td>Average calorie intake</td>
<td>2733</td>
<td>2744</td>
<td>3480</td>
<td>3806</td>
<td>3376</td>
<td>3545</td>
<td>4113</td>
<td>1874</td>
<td>2441</td>
<td>2781</td>
<td>3183</td>
</tr>
<tr>
<td>Deviation of weight from period II</td>
<td>+2%</td>
<td>+2%</td>
<td>+5%</td>
<td>+13%</td>
<td>+16%</td>
<td>+20%</td>
<td>+11%</td>
<td>+3%</td>
<td>+0.2%</td>
<td>+0.1%</td>
<td>-0.6%</td>
</tr>
<tr>
<td>Deviation of body surface from period II</td>
<td>+0.7%</td>
<td>+0.6%</td>
<td>+2.1%</td>
<td>+5%</td>
<td>-7%</td>
<td>+8%</td>
<td>+5%</td>
<td>+1.3%</td>
<td>+0.1%</td>
<td>+0.04%</td>
<td>-0.3%</td>
</tr>
<tr>
<td>Deviation of calorie intake from period II</td>
<td>-0.4%</td>
<td>+27%</td>
<td>+39%</td>
<td>+23%</td>
<td>+29%</td>
<td>+50%</td>
<td>-32%</td>
<td>-11%</td>
<td>+1.3%</td>
<td>+16%</td>
<td>+8%</td>
</tr>
<tr>
<td>Average daily change in weight</td>
<td>-0.68</td>
<td>-0.012</td>
<td>+0.141</td>
<td>+0.129</td>
<td>+0.030</td>
<td>+0.024</td>
<td>+0.091</td>
<td>-0.196</td>
<td>-0.069</td>
<td>-0.050</td>
<td>+0.063</td>
</tr>
</tbody>
</table>

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recorded, but care was taken not to make unsuitable use of those particular figures. An abnormally low weight (500 grams below the previous day) was found on November 27, 1917, at the onset of a heavy nasal catarrh. It was discarded, leaving November 26 the last valid weighing. No weights were discarded for any other causes.

It must not be forgotten that body weight is only an approximate criterion for the equality of intake and output. A person who is oxidizing as much as 100 calories (11 grams) of body fat a day, may replace enough of that fat with water and have enough other fluctuations of his water metabolism to completely mask the fact for many days. This makes it very necessary for experiments upon the body weight to cover long periods of time.

Low level tests of 1916. The initial low level tests are not to be understood as representing subnormal nourishment or any great degree of emaciation. At that time (age thirty-four) my weight had been fairly constant for a number of years, between 64 and 66 or possibly 66.5 kgm. This is below the average for the height of 181.2 cm., but if allowance is made for a rather short and narrowly built trunk, it does not necessarily indicate under-nutrition.

No record of activity was made during this period, but the round of occupations corresponded very closely to the recorded activities of May and June, 1917, the schedule of duties, the plan of life and the daily habits being almost identical. This means about five miles a day by pedometer, about forty-five meters of staircases climbed per day, and a variety of light occupations connected with teaching and laboratory, many of which are already included in the estimated mileage. Night hours and habits of sleep were good, averaging not far from 8.2 or 8.3 hours rest per night. It should perhaps be mentioned that I am not a quiet sleeper. By fastening a pedometer to one ankle, it was found that in an average night 150 to 160 movements would be made, of sufficient vigor to be counted as steps by the pedometer. No sports, muscular games or pleasure walks were indulged in during any of the experimental periods upon measured diets. On this quiet manner of life, starting at a weight (on March 3) of 64.16 kgm., it was attempted to establish a nutritive balance at about 2725 calories. This diet was probably a little less than was eaten before the experiments. As long as it lasted the sensations of hunger before meals were more than customarily acute.

For the entire duration of the test, till May 9, the tendency to lose weight was not entirely overcome. The 41-day period, March
WEIGHT REGULATION IN MAN DURING OVER-NUTRITION

30 to May 9, 1916 (period II), shows an average daily loss of 12 grams on 2744 calories of food, at an average weight of 61.81 kgm. Thus the body requires more than 2744 calories to sustain it at 62 kgm, even under the very moderate conditions of activity. Assuming that the 12 grams of flesh lost had a calorie value not higher than fat, the daily expenditure was more than 2744 and less than 2855 cal. A similar calculation from the last seventeen days of this period gives an expenditure of more than 2753 and less than 2827 cal.

These figures are distinctly larger than the ordinary expectation at the indicated degree of activity. Based on a height of 181.2 cm. and a weight of 61.8 kgm., the expected output of energy can be listed approximately as follows:

<table>
<thead>
<tr>
<th>Item</th>
<th>Calories</th>
</tr>
</thead>
<tbody>
<tr>
<td>Basal metabolism, 24 hours</td>
<td>1593.0</td>
</tr>
<tr>
<td>Added for 5.8 hours sitting, $\frac{5.8}{24} \times 0.1 \times 1595$</td>
<td>38.5</td>
</tr>
<tr>
<td>Added for 10 hours standing, $\frac{10}{24} \times 0.2 \times 1595$</td>
<td>132.1</td>
</tr>
<tr>
<td>Added for walking 5 miles, $5 \times 0.6 \times 65.4$ (i.e., clothed weight.)</td>
<td>197.2</td>
</tr>
<tr>
<td>Added for estimated activities that fail to show on the pedometer (50 per cent of the walking)</td>
<td>98.6</td>
</tr>
<tr>
<td>Added for climbing 45 m. of stairs, $45 \times 4 \times 65.4 \times 0.002343$</td>
<td>27.6</td>
</tr>
<tr>
<td>Added for descending 45 m. of stairs, $45 \times 2 \times 65.4 \times 0.002343$</td>
<td>13.8</td>
</tr>
<tr>
<td>&quot;Digestion cost&quot; of 2744 cal. food (6 per cent)</td>
<td>164.6</td>
</tr>
<tr>
<td>Predictable calorie output</td>
<td>2267.4</td>
</tr>
<tr>
<td>Food eaten</td>
<td>2744.0</td>
</tr>
<tr>
<td>Discrepancy of intake over predictable need</td>
<td>476.6</td>
</tr>
<tr>
<td></td>
<td>or 21 per cent</td>
</tr>
</tbody>
</table>

Where some of these items are problematical, they have been estimated at a rather liberal rate, e.g., the ten hours standing and the unknown activities equivalent to 2.5 miles of walking. The "digestion cost," and the increments of metabolism due to the sitting and standing positions have been placed at figures that may appear rather low, because the data upon these factors published in recent years by F. G. Benedict and his collaborators seem to call for a moderate estimate

1 Harris and Benedict's prediction for height, 181.2 cm.; weight, 71.81 kgm
2 Assuming a mechanical efficiency of 25 per cent.
3 Assuming the descent to cost half as much as the ascent.
4 Benedict and Carpenter (22).
of their effect. (See Benedict and Murschhauser (20); Benedict and Carpenter (22).)

The failure to overcome the negative balance on an intake of 2744 calories indicates a physiological tendency, even at low weight levels, to expend more energy than is to be expected from the list of external activities. This physiological wastefulness left the system slightly under-nourished on a diet which ought otherwise to have been more than adequate.

High level tests. May, 1916, to June, 1917. Periods III and IV of the experiments, covering May 10 to June 12, inclusive, differ from the preceding in an increased amount of carbohydrate with a slight increase of butter (50 instead of 35 grams). In order to avoid overwhelming the stomach with an excessive volume of food, the additions were chiefly to the bread ration rather than the moist cereals. For two weeks (period III) a diet of 3480 cal. was maintained, on which a gain was made of 2.25 kgm. As there was no promise of reaching a balance quickly, a further increase of bread was made and the high feeding was kept up till June 13 (period IV, May 26 to June 13, inclusive). With an average diet of 3806 calories, the daily gains continued about the same, to the final weight of 66.17 kgm.

Periods III and IV can count only as preliminary, being too short to overcome the doubts that are necessarily caused by the fluctuation of water metabolism. It is well known (Bischoff and Voit (23); Voit (24) discussion on page 347) that heavy feeding with a very starchy diet will lead to a notable accumulation of water in the tissues. But we have no basis on which to predict the extent or duration of this process, and so have hardly any clue to the calorie value of the accumulated weight in our experiment. If the accumulation during period IV had been exclusively pure fat,—an assumption which is certainly contrary to fact,—it would have represented a fuel accumulation of 1200 calories per day, or more than the total daily excess of food in calories. The high diet needs to be continued long enough to more nearly stabilize this factor of water intake.

The summer, from June 14 to October 23, was on a liberal and hearty diet. Butter, meat, milk and especially all forms of carbohydrates were supplied unstintingly, and were intentionally taken to the full limit that could be relished. For 24 months the appetite was under the stimulus of an active outdoor life. The resulting weight of 70.05 kgm. on October 24 was considerably the largest that I had ever reached.
There then followed a measured period of fifty days (period V) averaging 3376 calories per day, and with daily activity at most only slightly greater than in the other experimental periods. The average gain during the fifty days was 30 grams per day. This must be interpreted as showing a genuine plus balance, because the gain is distributed throughout the period, including its latter portion when water equilibrium must have been reasonably well established. The small size of the daily gains makes it seem probable that the fuel cost of maintenance and activities had risen along with the body weight.

The period of over-nutrition was unavoidably interrupted in the winter of 1916–1917 by a season of heavy duties, impaired sleep and consequent intolerance for an excessive diet. But there was no interruption of the record of essentially good health, and in February and March good nutritive conditions made it possible to recover the greater part of what had been lost.

On March 24, 1917, period VI was started with the initial weight of 71.20 kgm. It was continued 73 days with an average intake of 3545 calories of food and showed an average gain of 24 grams per day. As in the case of the preceding period, the weight curve does not suggest any modification of the water metabolism by the carbohydrate food. Its greater length renders it a comparatively safe period on which to base calculations. With an average weight only 1.03 kgm. above that of period V the additional 170 calories are carried with a smaller daily gain. There seems, then, to have been a definite although not very great growth of that extravagance in use of fuel food which was noted during period II.

This high expenditure of fuel food is much more pronounced in this period than in any previous test. This is not explained by activity, as the daily habits of period II and period VI are the nearest imaginable approach to duplicates of each other. It is likely that period V had slightly, but only slightly greater physical activity, on account of a slightly heavier schedule of university duties. In that case the relative metabolism of period VI above period V becomes the more noteworthy. Period V is the only one of the first six periods that differed perceptibly in its round of activities.

The record of activities with the aid of pedometers began to be taken that spring, and included about four weeks of period VI. Three pedometers were worn at the start, one at the belt, a second at the right ankle, intended to show minor movements of locomotion, and the third at the right forearm. The forearm position proved to be use-
less, because of the changes of posture, and because sudden motions were liable to jam the bob of the pedometer and make it stop recording. The ankle pedometer was also given up eventually. It seemed to be able to record more motions than the belt pedometer during the sitting and standing occupations, but it suffered from very nearly the same mechanical difficulties as the one on the arm. It was read night and morning for 14 days, and supplied the data on restless sleeping to which I have already referred. The belt pedometer was worn only during the waking hours, and was read once daily regularly through the remainder of the series of experiments.

The estimate of stairs climbed is a fairly accurate average, based on the extremely uniform round of places visited each day.

The record of hours devoted to sleep did not commence till July of that year. They vary from 8.20 to 8.35 hours in different months. I believe it probable that in periods I to VI the hours were not less than the latter figures, but in order to insure against an under-estimate of activities, I have calculated on the basis of 8.2 hours.

A rather problematical point as regards activity is the number of hours in the standing position, and the amount of activity of gentler type than would record on the pedometer. Much time was spent standing, as I made but little use of chairs in the laboratory. In order to insure against an under-estimate, the figure has been set at ten hours for periods I to VI inclusive. In the same spirit I have assumed an arbitrary figure of half the energy of an average day's walking to cover the undeterminable lighter activities. These data give us the following estimate of the daily energy output that would fulfil the ordinary expectation for this period:

<table>
<thead>
<tr>
<th>Description</th>
<th>Calories</th>
</tr>
</thead>
<tbody>
<tr>
<td>Basal metabolism, 24 hours</td>
<td>1724.0</td>
</tr>
<tr>
<td>Added for 5.8 hours sitting, ( \frac{5.8}{24} \times 0.1 \times 1724 )</td>
<td>41.7</td>
</tr>
<tr>
<td>Added for 10 hours standing, ( \frac{10}{24} \times 0.2 \times 1724 )</td>
<td>143.7</td>
</tr>
<tr>
<td>Added for walking 4.82 miles, ( 4.82 \times 0.6 \times 75.4 ) (i.e., clothed weight)</td>
<td>218.1</td>
</tr>
<tr>
<td>Added for activities not shown on pedometer (estimated as 50 per cent of the walking)</td>
<td>109.0</td>
</tr>
<tr>
<td>Added for climbing 45 m. of stairs, ( 45 \times 4 \times 75.4 \times 0.002343 )</td>
<td>31.8</td>
</tr>
</tbody>
</table>

5 Harris and Benedict's prediction for height, 181.2 cm.; weight, 71.81 kgrm.

4 Assuming a mechanical efficiency of 25 per cent.
WEIGHT REGULATION IN MAN DURING OVER-NUTRITION

Added for descending 45 m. of stairs\(^7\).............................. 15.9

"Digestion cost" of 3545 cal. food (6 per cent)\(^8\).................... 212.7

Predictable calorie output.................................................. 2496.9
Food eaten............................................................................. 3545.0
Deduction for excess feces (21 grams excess above the normal 30
grams) 21 \(\times 6.2\) cal......................................................... 130.2

Net cal. from diet................................................................. 3414.8
Discrepancy of intake over predictable need........................... +37 per cent

This diet seems, from the calculation, to be no less than 37 per cent
in excess of the predictable need, while the diet in period II showed an
excess of 21 per cent. But it is necessary to allow for the difference
between a falling weight in period II and a rising weight in the later
period. If we assume that the caloric value of the flesh gained and lost
does not exceed that of pure fat, then the total oxidation of material
(food and body fat) in period II lies 21 per cent to 23 per cent above
the predictable figure, and the oxidation in period VI is between 27 per
cent and 37 per cent above the prediction. The discrepancy between
the predictable and the observable expenditure has undergone an absolute
increase and probably even a relative increase.

Basal metabolism during over-nutrition. In June, 1917, the courtesy
of Dr. F. G. Benedict and of Dr. T. M. Carpenter and their collaborators
in the Carnegie Nutrition Laboratory supplied me with three determina-
tions of my basal metabolism by their usual routine methods. On
June 13 and 16 the tests were in the bed respiration chamber, Miss
Corson in charge, at the Deaconess' Hospital, Boston, and on June 20
by means of the large Tissot spirometer and Haldane gas analysis
methods, carried out by Doctor Carpenter. These tests were all of
them on the high diet, the average intake of the three 2-day periods
preceding these three tests being 3965 calories. As the experiments
necessarily interrupted the diet, being taken at breakfast time on an
empty stomach, and not being concluded for some hours, the average
intake for the whole period of June 9 to 19 inclusive is only 3790 cal.
On this diet of essentially 3965 calories representing the maximum in
take up to that date, and at a body weight of 73.62 kgm., the recorded
metabolism is very uniform with the single exception of the first respira

\(^7\) Assuming the descent to cost half as much as the ascent.
\(^8\) Benedict and Carpenter (22).
tion period of the first day, the period of introduction to the apparatus, when the psychic effects undoubtedly militated against complete relaxation. Rejecting this half-hour period, the average of the other results, by indirect calorimetry from the gas analysis, are 73.32 cal. per hour, or 1762 cal. per day for the waking basal metabolism. The prediction for weight 73.6 kgm., height 181.2 cm. and age thirty-five, made by Harris and Benedict (19) is 1749 cal., constituting an almost perfect agreement with the finding.

A very high respiratory quotient should be noted; the figures being 0.94, 0.93 and 0.89 on the three different days. In the first two of these cases the non-protein respiratory quotient was 0.98. Thus even thirteen to fifteen hours after the last meal, and although fats were by no means excluded from the high carbohydrate diet, the oxidative processes were limited practically to carbohydrate and protein.

In spite of this fact that the high carbohydrate of the previous evening is still exerting a great influence upon the respiratory quotient, the metabolic rate conforms exactly to the prediction for the basal or post-absorbptive rate. The prolonged diet has not raised the basal metabolic rate above the normal average.

As I believe the figures have demonstrated that the metabolism as a whole is extravagant above the average, we shall have to look for the element of extravagance in some other factor than the basal rate.

Return to normal level. The return to a normal weight was accomplished in the summer months of 1917, while at the laboratories of the University of Illinois Medical School. During this period the food, urine and feces were analyzed for the determination of nitrogen balance. The urine analyses were continued most of the time to the end of the experiments on November 26, and the weighed diet up to that date was limited to the same set of foods as were used in the summer period. Thus the nitrogen exchange was followed in full or in part during the whole of these 4½ months. Table 3 summarizes these analytical data.

The diet differed from that of previous periods in the substitution of shredded wheat in place of the more difficulty analyzable white rolls, and also in the change from soft boiled eggs to a form of custard, which could easily be sampled for analysis when mixed and strained and ready to cook. Clear centrifuged butter fat was used in the summer months in place of commercial butter. Head rice, Quaker brand rolled oats and whole milk completed the diet. The analysis of the milk was by taking equal daily samples. The shredded wheat was
### Table 3

**Summary of nitrogen exchange**

<table>
<thead>
<tr>
<th>PERIOD AND DATE</th>
<th>VII 1917 July 8–9</th>
<th>VII 1917 July 10–14</th>
<th>VIII 1917 July 15–24</th>
<th>VIII 1917 August 1 to August 7</th>
<th>VIII 1917 August 8–29</th>
<th>IX 1917 September 2–12</th>
<th>IX 1917 September 13 to October 8</th>
<th>IX 1917 October 9–12</th>
<th>X 1917 October 23</th>
<th>XI 1917 October 24–27</th>
<th>XII 1917 October 28 to November 10</th>
<th>XIII 1917 November 11–25</th>
</tr>
</thead>
<tbody>
<tr>
<td>Duration in days</td>
<td>2</td>
<td>5</td>
<td>10</td>
<td>14</td>
<td>22</td>
<td>3</td>
<td>11</td>
<td>25</td>
<td>4</td>
<td>1</td>
<td>4</td>
<td>14</td>
</tr>
<tr>
<td>Dietary N.</td>
<td>20.26</td>
<td>19.74</td>
<td>15.68</td>
<td>13.60</td>
<td>13.42</td>
<td>13.37</td>
<td>14.60</td>
<td>15.18</td>
<td>15.71</td>
<td>15.88</td>
<td>15.05</td>
<td>15.97</td>
</tr>
<tr>
<td>Urinary N.</td>
<td>14.30</td>
<td>16.02</td>
<td>14.10</td>
<td>13.23</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Fecal N.</td>
<td>3.54</td>
<td>1.59</td>
<td>1.27</td>
<td>1.02</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Daily N. balance</td>
<td>+1.89</td>
<td>-1.93</td>
<td>-1.82</td>
<td>-0.83</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>N. balance for period</td>
<td>+9.47</td>
<td>-19.34</td>
<td>-25.53</td>
<td>-18.35</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Loss in 6 days</td>
<td>63.2 gm.</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Calorie intake</td>
<td>4127</td>
<td>212</td>
<td>1811</td>
<td>1772</td>
<td>1788</td>
<td>2198</td>
<td>2537</td>
<td>2658</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Per day</td>
<td>avg. 4115</td>
<td></td>
<td>avg. 1874</td>
<td></td>
<td>avg. 2441</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Change of weight during period</td>
<td>+ 0.64</td>
<td>-9.58</td>
<td>-2.83</td>
<td>-0.55</td>
<td>+ 0.25</td>
<td>-0.57</td>
<td>-0.05</td>
<td>0.05</td>
<td>+0.063</td>
<td>-0.044</td>
<td>-0.003</td>
<td></td>
</tr>
<tr>
<td>Change of weight per day</td>
<td>+0.091</td>
<td>-0.196</td>
<td>-0.069</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

*12.01 grams in 6 days, November 14–19, inclusive.*
broken small and mixed thoroughly in a large, moisture-proof con-
tainer, from which the daily portions and the samples for analysis were
taken. The rolled oats and the rice were similarly mixed and sampled.
All these cereal samples were ground before dividing them into smaller
portions for the analyses. The Kjeldahl-Gunning method was used in
all the nitrogen determinations.

The first week of this summer series, on a diet of 4115 cal., represents
very nearly the maximum capacity of the subject for continuous
consumption, unless fats were to be used more freely. A substantial
plus balance is shown both in nitrogen and in body weight. The
period is too short to indicate the extent to which excess oxidation may
have developed, but it is clear that the process had not gone far enough
to prevent further fattening.

Following this was a period of low nutrition, lasting 7 weeks, with a
daily average of 1874 cal. The intention was to dispose of the accumu-
lated body fat without running into the condition of depressed basal
metabolism that will occur when there has been a heavy loss of nitrogen.
Accordingly the quota of eggs was somewhat increased, and the radical
cut was confined to the cereal foods and the butter fat, the latter being
entirely discontinued during most of the interval. It was impossible,
however, to prevent a strongly negative balance of protein materials,
so that the average daily weight loss of approximately 200 grams for
the rest of the summer is accompanied by an average nitrogen loss
of nearly 1.4 grams per day.

Final equilibrium. The attempts to reach a stable weight during
September, October and November make it clear, first of all, that in
spite of the considerable loss of nitrogen the body was by no means in a
depressed metabolic state. It is impossible to tell whether the body
was richer or poorer in protein constituents than it had been during
the first equilibrium period (period II) of 1916. After more than a
year of high caloric diet, with a fully adequate protein intake at all
times, there can be no question that when the diet was changed in
July the tissues were copiously stocked with protein materials. The
figures obtained after July 15 can be extrapolated so as to show that
between that date and the middle of September the body must have
lost some 70 or 75 grams of nitrogen,—an amount that probably did
not yet leave the body in any greatly depleted condition. When the
diet was now increased to near 2500 calorie, this negative balance was
checked, or possibly even changed to a small positive figure, but the
loss of weight was not entirely overcome. The same was true in the
period on 2780 calories in October, the nitrogen balance being somewhat further improved, but the weight still continuing to decline. A virtually steady weight was at last established on an appreciably higher diet, from October 24 to November 25 inclusive, but not till the nitrogen balance had become definitely positive. Judging from the final fortnight, (period XIII), 3200 calories were now necessary to maintain a body weight of about 61.3 kgm.

During September, 1917, it was impossible to make a satisfactory record of activity, because at that time the exigencies of changing to a new residence caused a temporary increase of manual labor. The October and November records are free from such complications, excepting that the use of a bicycle was commenced at this point, to get to and from work. Habits of sitting and standing were about as in the early months of experimentation. The recorded activities are as follows:

<table>
<thead>
<tr>
<th>Duration in days</th>
<th>X October 13-23</th>
<th>XI October 24-27</th>
<th>XII October 28 to November 10</th>
<th>XIII November 11-35</th>
</tr>
</thead>
<tbody>
<tr>
<td>Sleep per day, hours</td>
<td>8.55</td>
<td>8.44</td>
<td>7.78</td>
<td>8.28</td>
</tr>
<tr>
<td>Walking per day, miles</td>
<td>4.76</td>
<td>7.62</td>
<td>3.58</td>
<td>4.35</td>
</tr>
<tr>
<td>Bicycle per day, miles</td>
<td>2.01</td>
<td>4.48</td>
<td>4.54</td>
<td>4.77</td>
</tr>
<tr>
<td>Stairs climbed per day (est.) meters</td>
<td>20</td>
<td>20</td>
<td>20</td>
<td>20</td>
</tr>
</tbody>
</table>

The bicycle route involved no steep grades, and always returned to the level of the original starting point. The bicycle was an exceedingly easy running one, capable of coasting freely on windless days on a gradient of 115 feet (35 m.) per mile, rider plus bicycle having a total weight of 83 kgm.

Without attempting to evaluate the energy used in bicycle riding, I believe it will be conceded to be insufficient to make the activities of the above periods appreciably greater than in periods II and VI. But the irregularities in sleep are probably a rather serious factor, and period XII is probably vitiated for purposes of comparison by the relatively poor "sleep" record. For this reason period XIII seems to be the principal one for a satisfactory comparison with period II, on the assumed basis that they represent essentially the same degree of muscle activity.
The summarized results of the last four periods are as follows:

<table>
<thead>
<tr>
<th>PERIOD</th>
<th>DATES</th>
<th>INTAKE IN CALORIES</th>
<th>CHANGE OF WEIGHT PER DAY</th>
<th>REMARKS</th>
</tr>
</thead>
<tbody>
<tr>
<td>X</td>
<td>October 13-23</td>
<td>2781</td>
<td>-50</td>
<td>Maximum sleep. Activities below average</td>
</tr>
<tr>
<td>XI</td>
<td>October 24-27</td>
<td>3183</td>
<td>+63</td>
<td>Excellent sleep. Greater activities</td>
</tr>
<tr>
<td>XII</td>
<td>October 28-November 10</td>
<td>2970</td>
<td>-44</td>
<td>Imperfect sleep. Moderate activities</td>
</tr>
<tr>
<td>XIII</td>
<td>November 11-25</td>
<td>3204</td>
<td>-3</td>
<td>Excellent sleep. Moderate activities</td>
</tr>
</tbody>
</table>

I place beside these for comparison the earlier period:

| II     | March 30-May 9, 1916 | 2744               | -12                      | Excellent sleep. Moderate activities |

In spite of the inescapable irregularities inherent in human experimentation of this sort, a comparison of the forty-one days in 1916 with the final thirty-three days, both of which were at practically

![Chart of food intake and body weight, 1916](http://ajplegacy.physiology.org/DownloadedFrom/)
Chart of food intake and body weight, 1917.
identical average body weights, brings out very definite evidence of a marked increase in the daily caloric requirement. It is not safe to attempt to calculate exactly how great this change has been, but on the face of the results from the final fifteen days, the daily demand seems to have risen by some 300 to 400 calories.

**DISCUSSION**

The general results of these experiments are that this example of a person belonging to the difficultly fattening type was found to show a wasteful rate of oxidation during all the feeding experiments, including both the periods in which the diet was moderate or low and those in which a large excess of starch was superposed upon the normal diet. During the prolonged periods of high diet this wasteful oxidation became more pronounced and it continued so throughout the following periods of under-nutrition, so that even after the body had been brought down again to its original weight, it required more food to keep it at steady weight than had been necessary at the start.

In a preliminary report of these experiments that was made in 1917 (25) considerable uncertainty was expressed as to whether or not these figures could be used as evidence for a compensatory excess oxidation during high feeding. This doubt was based on the fact that a comparison between the nutritive exchange during high feeding and that during the final low-weight periods could only lead to inconclusive results. In the present paper the final low-weight periods are not used for this comparison, and the extravagance of the calorie exchange during over-nutrition is appraised by comparing it with the initial determination of minimum need, as made in 1916. It is believed that this plan of analysis is justified; firstly, because the calorie demand in the final periods is so far above the need as found in 1916 that it seems to show a hangover effect from the months of excess nutrition; and, secondly, because even the initial need is noticeably in excess of the expectation by dead reckoning.

The basal rate of metabolism as determined in a reclining position before breakfast did not rise above the average expectation for the subject's age, weight and height. Pulse and blood pressure were also entirely normal.

It seems clear that throughout the entire experimental series there was some factor at work which caused fuel food to be burned more freely than in the average individual. This factor was not an overactive thyroid as attested by the entirely normal basal metabolism.
It is possible that a part of the waste is attributable to neuromuscular factors. During all the experimental periods the greater part of the daily activities were of the less intense variety, the calorific cost of which is always problematical, because it can never be predicted how much will be wasted in the increased tone of the unemployed muscles. This undeterminable expenditure may easily have varied from the average expectation, and may be responsible for some of the unexplained energy expenditure. But if this were the whole explanation, we ought to find a lessened wastefulness and not an increase during the months of over-feeding when there was a continued stuffed feeling and a disinclination to exertion. For this reason it seems more probable that the main factor is not to be sought in neuromuscular habits, but in some factor in the chemistry of nutrition.

The nitrogen balance may very easily be connected in some way with this problem, for although the actual intake of proteins was never abnormally high, the liberal calorie allowance of the experimental diets and of the subject's previous dietary habits was very favorable to an accumulation of nitrogen. Even the last tests, after there had been a loss of 70 grams or more of nitrogen, may have been under the influence of superabundant stores of protein materials, as that 70 grams were only removed after a maximum storage must have been attained, and by the time that the last experimental weeks had been reached, some of the lost nitrogen had been restored. If the factor causing extravagance is related to this supposed nitrogen enrichment, it is not to be compared with the plethora effect observed by Atkinson and Lusk (5), but it may very possibly be comparable to the "secondary effect" of protein enrichment, which according to Rubner (1) can raise the specific dynamic effect of the food without raising the basal rate. The present experiment differs from Rubner's in that the food for which the specific dynamic effect must be augmented is largely starch instead of protein.

It is also possible that nitrogen enrichment may not be the major explanation of the nutritive condition. For there is still the alternative that von Noorden's (15) suggestion respecting the obese type may have its converse, and the spare type be accounted for by any factor that produces a high "cost of digestion," just as the obese may be supposed to suffer from an abnormally low "cost of digestion." The decision between these alternatives would only be possible after an extension of the tests beyond the limits that have been practicable in the present investigation.
SUMMARY

1. During periods aggregating about three hundred and seventy days on experimental diet, a person of the difficultly fattening type was investigated, first, to determine the minimum food required for maintenance of weight at the customary level; second, to ascertain whether and to what extent an excess of starchy food would be stored by this type of person as adipose in a long period of superabundant measured diet; and third, to ascertain whether after the body was returned to the initial weight with least possible loss of nitrogen, any change had occurred in the minimum requirement of food.

2. The person was found to owe his resistance against fattening to an extravagant calorie requirement which persisted at all times, despite a moderate daily round of activities.

3. This extravagance increased during the course of the excessive carbohydrate diet, and stayed above the initial level even after the return to normal weight.

4. The basal metabolic rate was not involved, but remained strictly normal.

5. The high calorie output and consequent resistance against fattening may find its explanation either in a condition of nitrogen enrichment, or in an upward variation of the "cost of digestion" (and assimilation) of starchy food.

Grateful acknowledgments are due to the Nutrition Laboratory of the Carnegie Institution, to Dr. F. G. Benedict, in charge of that laboratory, to Miss Corson, at the Deaconess' Hospital, Boston, and particularly to Dr. Thorne M. Carpenter for active interest in the determination of basal metabolic rate in June, 1917; and to the University of Illinois Medical School, Laboratory of Physiological Chemistry, Chicago, where I received liberal backing for the portions of the work done in July and August, 1917, through the generous recommendation of Dr. W. H. Welker. All other parts of the experiments here reported are from the Laboratory of Physiological Chemistry, Department of Physiology, University of Missouri.

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