THE NATURE OF OBESITY

L. H. Newburgh, Margaret Woodwell Johnston

J Clin Invest. 1930;8(2):197-213. https://doi.org/10.1172/JCI100260.

THE NATURE OF OBESITY[1,2]

L. H. NEWBURGH AND MARGARET WOODWELL JOHNSTON

(From the Department of Internal Medicine, Medical School, University of Michigan, Ann Arbor)

(Received for publication April 22, 1929)

The medical profession in general, believes that there are two kinds of obese persons—those who have become fat because they overeat or under-exercise; and those composing a second group whose adiposity is not closely related to diet, but is caused by an endocrine or constitutional abnormality.

The first apparently scientific support of the hypothesis that obesity was often of endogenous origin, came with the finding that some obese persons had an abnormally low basal metabolic rate, on the basis of body weight. When, however, it was shown that the expenditure of energy is proportional to the surface area and not the weight, it was found that most such persons have a normal basal metabolic rate. However, it is true that there remains a small group of fat people whose basal rate is definitely low.

Later writers maintained that a common cause of endogenous obesity was to be found in a lessened specific dynamic response to food. But the increase in metabolic rate caused by food is relatively small, so that a method possessed of a high degree of accuracy is needed in order to deal quantitatively with this phenomenon. Our prolonged study of this question has convinced us that the inherent error in the method to date, when it is applied to the human subject, is such that it precludes the possibility of making quantitative statements regarding the specific dynamic response to food in man.

Other writers have attributed endogenous obesity to a constitutional anomaly of the cells which somehow lowers the rate of intracellular oxidations.

[1] Address delivered before the American College of Physicians.

[2] Aided by a grant from The Fellowship Corporation.

But even if there were a group of obese people who possessed all these metabolic faults, we would still be without an adequate explanation for the occurrence of the adiposity. For 1—many persons of normal stature show abnormally low metabolic rates. For example, the average of a number of determinations in a middle aged woman under our care, who weighs 130 pounds, is 40 per cent below normal. A tall,

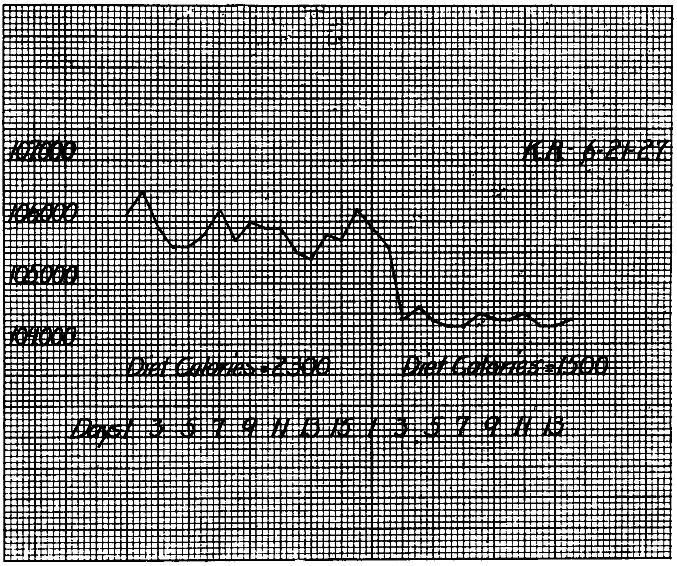

FIG. 1. RESPONSE OF AN OBESE SUBJECT TO UNDERNUTRITION

The diet in the first period is at the maintenance level. In the second period, no weght is lost for eleven consecutive days even though the diet is deficient to the extent of 800 calories daily.

slight young man regularly has a basal metabolic rate which is 25 per cent below normal. Myxedematous patients may lose weight. 2—The same writers who attribute endogenous obesity to a lessened specific response to food, describe other forms of pituitary disease characterized by the small increase in metabolic rate due to food, but without adiposity. 3—On the other hand the well known fall in basal metabolic rate caused by undernutrition in the normal subject, often fails to occur in the type of obesity under consideration (1); and further, it has recently been established that the obese subject uses more energy to perform a given piece of work than does the normal person (2).

These considerations lead to the conclusion that the fundamental cause of endogenous obesity is not to be found in some type of metabolic abberation; but rather, that these individuals, in common with all obese persons, are the victims of a perverted appetite. In normal people there is a mechanism that maintains an accurate balance between the outgo and the income of energy. All obese persons are, alike in one fundamental respect,—they literally overeat.

Regardless of any theoretical consideration, it is a fact that obese persons may fail to lose weight for a number of days when they are being undernourished. We have repeatedly recorded this striking phenomenon. For example, figure 1 is a portion of the weight record of a girl who weighed 231 lbs. During the first period she received her maintenance calories. In the second period, when she was deriving 800 calories a day from her body, she lost no weight for eleven consecutive days. It is this startling fact that is behind the search for some hidden metabolic fault inherent in these subjects. We likewise, have centered our attention upon this feature but have attempted its explanation with a new point of view In the past it has been customary to determine the basal metabolic rate and then guess how many additional calories were used during the twenty-four hours. When a diet containing less energy than the subject was thought to be using, was fed, the extra calories used by the subject but not contained in the diet, were assumed to arise from the oxidation of body fat, and the number of grams of fat required to make up the caloric deficit of the diet, formed the basis for the prediction of the amount of weight that the subject should lose.

We have considered such methods too inaccurate. Above all, it seemed necessary to have a means of getting an actual quantitative determination of the total outgoing calories. Fortunately recent studies by Benedict and Root (3) have made such a method available for the basal state, and we have been able to adapt it to our special problem.

It was understood many hundred years ago that there was a constant exhalation of invisible material from the body. Sanctorius (1614) made many observations to determine the amount of this "insensible perspiration." The subject has been studied sporadically ever since, but Francis G. Benedict and his collaborators were the first to point out that there is a quantitative relationship between the amount of weight lost by the body insensibly and the metabolic rate. They found that when a subject in the basal state is suspended from one arm of a delicate balance, he loses weight at an even rate. For example, a loss of 30 grams per hour corresponds to a metabolic rate of 1405 calories per twenty-four hours. We have been able to confirm this observation for the basal state; and further have found that the

TABLE 1

Determination of total calories for 24 hours

I		II	
	grams		*grams*
First body weight	62,260	Second body weight	61,900
Weight of food	1,599	Weight of urine	1,157
Weight of water	378	Weight of stool	0,000
	64,237		63,057
	63,057		
	1,180		

1,180 grams is insensible loss for 24 hours

$$\frac{1,180}{24} = 49.2 \text{ grams insensible loss per hour}$$

or

2,000 calories for the 24-hour period.

same principle may be applied in the determination of the total number of calories lost in twenty-four hours. If a subject is weighed at the beginning and end of a twenty-four hour period and if the weight of food and drink are added to the first body weight, and the weight of the urine and stool are added to the second body weight, the difference between the first and second sums is the insensible loss for twenty-four hours. From this figure the loss of weight per hour is obtained and finally, by means of Benedict's prediction table, the total calories for the period.[3]

[3] We have discussed the sources of error and indicated the high degree of accuracy obtainable by this method in another publication (4).

For the sake of clarity the figures used to determine the total calories for a single twenty-four hour period are reproduced in table 1.

Of equal importance with a method for determining the energy used by an individual, is an acurate knowedge of the response by a normal person to undernutrition. May he perhaps also fail to lose weight in accord with the expectation?

Fortunately we have been able to obtain this information by means of one of the laboratory staff who acted as the subject His coöperation was perfect at all times and his absolute honesty is beyond question.[4] Briefly, the man remained in bed, except when he stepped from it to the adjoining scale to be weighed or to the commode, a few feet away, to void or defecate into the special receptacles provided, or to place himself on a wheel chair by means of which he was moved to the laboratory where the basal metabolic rate was determined. His diet consisted solely of milk, sugar and water. His intake of these materials was weighed to one tenth of a gram and a sample of the milk was analysed for water content, nitrogen, fat, ash and carbohydrate. The excreta were similarly weighed and analysed. We accordingly had the following data to deal with:

(1) The subject's weight within 5 grams every morning at 8:40.
(2) The weight of food and drink.
(3) The weight of the urine and stool.
(4) The precise composition of the diet.
(5) The total outgoing nitrogen, total urinary solids, the amount of fat and carbohydrate in the stool.

This permitted us to calculate:

(1) The twenty-four hourly insensible loss of weight from which we derived the total outgoing calories for each twenty-four hours.
(2) The calories of the diet.
(3) The calories derived from the body to make up the difference between the ingoing and outgoing calories.
(4) The total amount of protein burned (total N out $\times$ 6.25).
(5) The protein loss from the body by substraction of the dietary protein from total protein burned.

---

[4] Space will not be taken here for a complete description of this study, the details of which are published elsewhere (5).

(6) The metabolic mixture, that is, the materials oxidized each twenty-four hours. This consisted of the total protein burned, plus the carbohydrate[5] of the diet, plus the amount of fat that would furnish the calories used by the subject, not contained in the protein and carbohydrate oxidized.

(7) The predicted loss of weight. The difference between the protein of the diet and that of the metabolic mixture and between the fat of the diet and that of the metabolic mixture, give the weight of the protein and fat lost by the body. Each of these substances has water physically

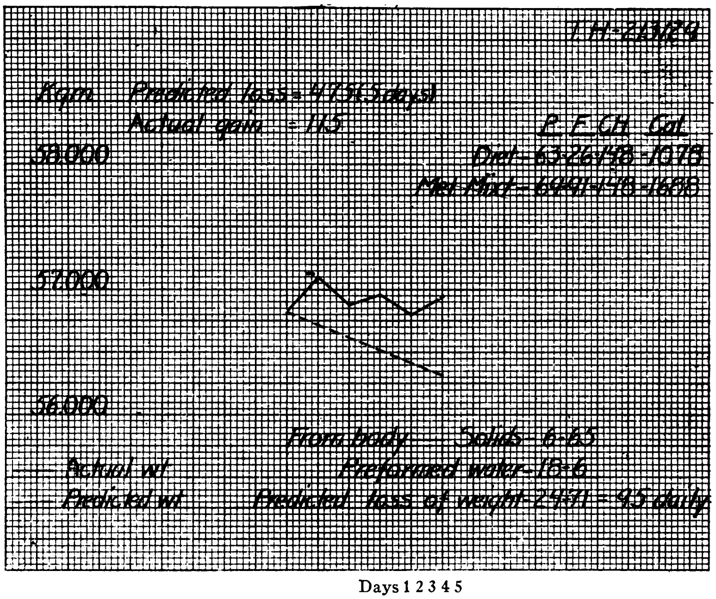

FIG. 2. RESPONSE OF A NORMAL SUBJECT TO UNDERNUTRITION

He gained 115 grams in 5 days instead of losing 475 grams

attached to it which is released and free to leave the body when they are oxidized. Protein is considered to hold 300 per cent and fat 10 per cent of its weight as "preformed water." The predicted loss of weight is then the sum of the weights of the protein and fat destroyed and the preformed water.

In figure 2 a short portion of our study of the normal subject is represented graphically. The diet consisted of protein 63 grams; fat

[5] Permissible because in undernutrition, all the carbohydrate of the diet is used.

26 grams; and carbohydrate 148 grams; and contained 1078 calories. The total calories used by the subject averaged 1688 for each twenty-four hour period. The metabolic mixture burned to furnish that amount of energy was: protein 69 grams; fat 91 grams; carbohydrate 148 grams, and the destruction of body protein and fat were consequently, 6 grams and 65 grams respectively. The weight of the protein plus the water held by it (300 per cent) and of the fat and its water

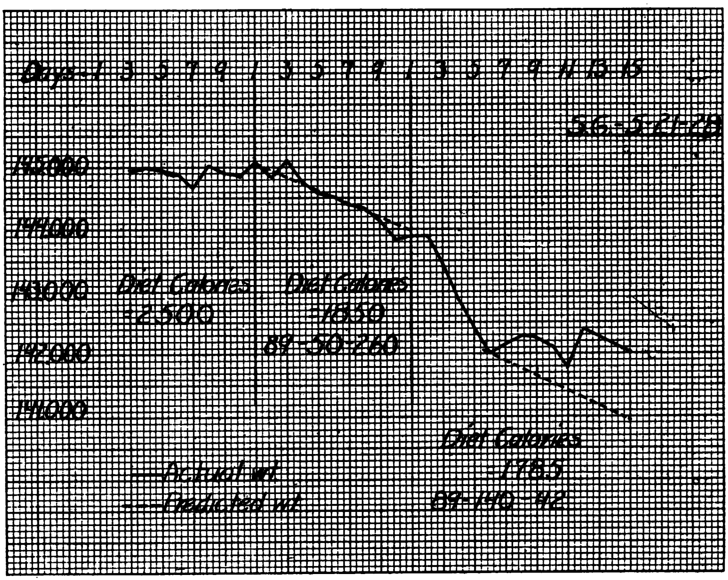

FIG. 3. RESPONSE OF AN OBESE SUBJECT TO UNDERNUTRITION

The maintenance of weight in the third period is contrasted with the expected loss of weight in the second period.

(10 per cent) was 95 grams. The subject would accordingly be expected to lose 95 grams daily. This predicted loss of weight is represented in figure 2 by the broken line. His actual weight is indicated by the solid line. It is evident that he gained weight for five days. Since the initial weight was 56,815 grams, he should at the end of five days have weighed 56,340 grams but he did, in fact, weigh 56,930 grams, that is he had gained 115 grams and weighed 590 grams more than the prediction. Here then is the production in a normal subject

of the very phenomenon whose occurrence in obese individuals had, in the minds of earlier writers, marked such persons as the victims of some endocrine or other constitutional dyscrasia.

Since a normal man may gain instead of losing weight even though he takes in less energy than he uses, it is clear that this event can no longer be held to give any specific information about the nature of the obesity.

As further evidence of the nonspecific character of this paradoxical conduct of the weight, figure 3 is presented. The patient whose response to undernutrition is here recorded was a woman of 26 years who freely admitted that she had been overeating for a long time and that she sought our help in breaking what she herself recognized as a bad habit. Except for obesity she presented no abnormalities. Her basal metabolic rate was normal.

Three consecutive periods are reproduced in figure 3. During the first one she received a maintenance diet. The second one is the record of a simple loss of weight due to undernutrition which adheres closely to the expectation. But this is abruptly followed in the third period by maintenance of weight for 9 days even though undernutrition is still in effect. Here then we have in a single obese subject, first a loss of weight characteristic of (so-called) simple obesity, and shortly thereafter the failure to lose weight, that, by contrast, has been dignified as a pathognomonic sign of endogenous obesity.

It is a relatively simple matter to cause either variety of weight curve. If it is desired to have the subject, whether normal or obese, lose weight regularly day after day, he is fed a diet whose calorific value is less than the energy used by him, but containing an abundance of carbohydrate. When the intention is to obtain a plateau in the weight curve, a diet is fed that not only yields less than the maintenance calories but is also poor in carbohydrate. This restriction of the dietary carbohydrate will cause the organism to deplete its store of liver glycogen and will inevitably cause a rapid loss of weight. When a balance has been reached between the exogenous and endogenous carbohydrate, the destruction of glycogen diminishes, and, at this time the subject may abruptly stop losing weight or may even gain for some days.

When an individual is undernourished, the shape of the weight curve is determined by the quality of the diet, and is in no sense dependent upon the constitutional or endocrinal state of the individual.

The ability of an individual to maintain his weight when the conditions are such that a continuous loss of adipose tissue is expected, has been interpreted by some observers as evidence that such persons are endowed with a special type of metabolism which, seemingly, is not constrained to obey the law of the conservation of energy. It is however, not necessary to go so far afield for an answer to what, on the sur-

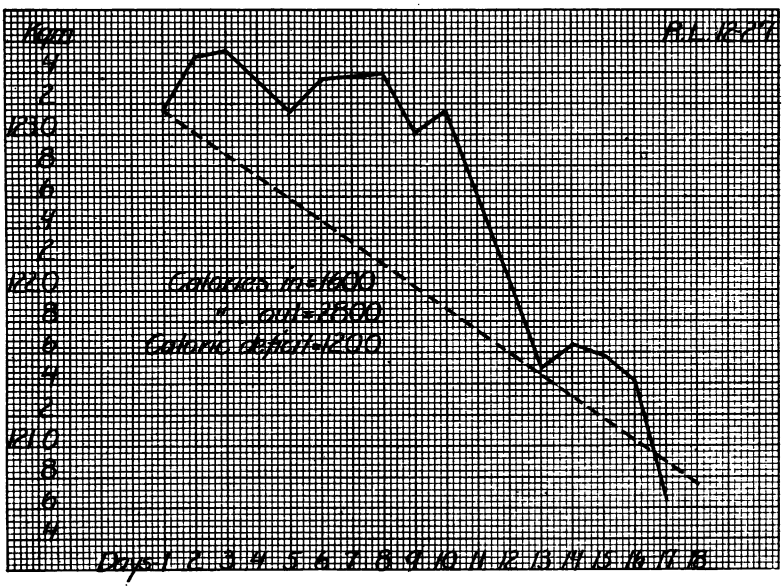

Fig. 4. Undernutrition, a Plateau in the Weight Curve Is Followed by an Excessive Loss of Weight

face appears to be a hopelessly involved set of phenomena. If the conditions that have caused a plateau in the weight curve be continued it will be observed after a few more days that an abrupt downward inclination in the curve has taken place and that the individual is now losing weight at a much more rapid rate than can be accounted for by destruction of body tissue. This excessive loss of weight continues until the total loss calculated from the beginning of the plateau approximately equals the predicted loss due to the oxidation of body tissue. Figure 4 is a typical example of this phenomenon. The patient was a young woman who weighed 275 pounds when admitted to the hospital. She had a basal metabolic rate of 2100 calories. The diet yielded 1600 calories.

This departure from the simple straight line loss of weight might be caused by alternate hydration and dehydration of the body accompanying the steady destruction of tissue in amounts that adhere closely to the prediction. We have accordingly carried out a quantitative study of the water exchange in a number of obese persons and in our normal subject. On one side of the equation is all the water which

TABLE 2

Determination of water lost insensibly

I		II	
	grams		*grams*
First weight	57,790	Second weight	57,840
Weight of food	2,041	Weight of urine	1,108
Weight of water	75	Weight of stool	0,000
Weight of oxygen	570	Weight of CO_2	628
	60,476		59,576

60,476
59,576
900 Water lost insensibly

becomes physically free during the period and must therefore be dealt with by the organism. For convenience we have called this the "available water." On the other side is all of the water lost from the body during the period.[6]

The available water is the sum of the (1) water drunk as such; (2) the water content of the food; (3) the water made by oxidizing the hydrogen of the metabolic mixture; (4) the preformed water which is water held by the body tissues and released when they are destroyed to supply energy. The water that leaves the body is the sum of the (1) water of the urine; (2) water of the stool; (3) water lost insensibly from lungs and skin. This last can only be determined by difference.

[6] This subject is dealt with only in outline in this paper. For technical and other details the reader is referred to our special publication (5).

The method is as follows: To the weight of the subject at the beginning of the period is added the weight of food and drink and the weight of the oxygen added to the body for the combustion of the metabolic mixture. From this sum is subtracted the sum of the weight of the subject at the end of the period, plus

TABLE 3

Water exchange

Available water		Water lost	
	grams		*grams*
Drank	75	In urine	1,069
In food	1,799	In stool	0,000
Preformed	41	Insensibly	900
By oxidation	229		1,969
	2,144		

2,144	
1,969	
175	Water retained

TABLE 4

Actual		Predicted	
Change in weight			
	grams		*grams*
First body weight	57,790	Body protein plus preformed water	44
Second body weight	57,840	Body fat plus preformed water	85
Gain	50	Loss	129
Retention of water			
	grams		*grams*
(From analytical data)	175	Predicted loss of weight	129
		Real gain in weight	50
			179

the weights of the urine, stool and the carbon-dioxide exhaled. The calculation of the weight of the insensible water from the data for a single twenty-four hour period will be found in table 2.

In table 3 the calculation of the total water exchange for the same twenty-four hours is given.

On this day when the subject retained 175 grams of water, the inflow and outflow of energy was such that he should have oxidized body tissues, which together with the water physically held by them, weighed 129 grams. In spite of this, the body weights recorded, show a gain of 50 grams. To account for this gain in terms of water, he should have retained 179 grams. From our calculations were found a retention of 175 grams (table 4).

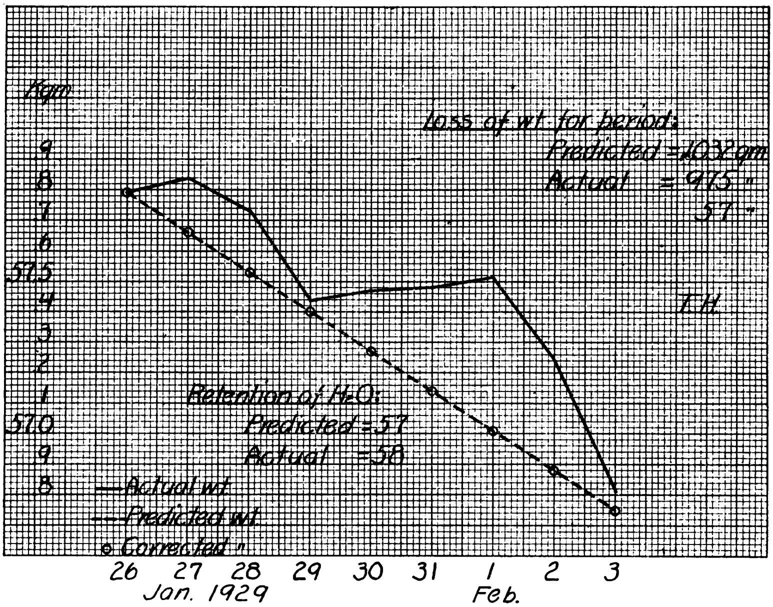

FIG. 5. NORMAL SUBJECT DURING UNDERNUTRITION

When the actual daily weight is corrected by the amount of water retained or lost the resultant (indicated by circles) has the same value as the predicted weight.

These studies have brought out the fact that the body weight is the combined result of two processes which may act in the same direction or be opposed to each other. On the one hand there may be either an addition to the body or a loss from it of solid material, determined by the relation between ingoing and outgoing calories. On the other hand, and independent of it, a retention or loss of water may occur. Accordingly, when it is desired to use changes in body weight as a measure of the amount of body tissue destroyed to make up the caloric deficit of a diet, it is necessary to correct the actual body weight by the weight of the water added to or lost from the body.

We have in this manner corrected the day to day weights of a number of persons in the state of undernutrition. Various types of obese persons as recorded in the literature were included; that is, an individual physically normal except for adiposity who frankly admitted years of gluttony; a feeble minded girl with an abnormally low basal metabolic rate; a girl with pituitary disease and a basal rate 30 per cent

TABLE 5

Diet (by analysis): Protein 63; Fat 26; Carbohydrate 148; Calories 1079
Calories used each 24 hours: 1818
Total N out (24 hours): 11.8 grams
Metabolic mixture: Protein 74; Fat 103; Carbohydrate 148

From body (daily): Protein 11; Fat 77; Water 41
Predicted loss (daily): 129 grams

Loss for period (8 days)

	grams
Predicted	1032
Actual	975
Difference	57

Retention of water

	grams
Predicted	57
Actual	58

below normal; a middle aged woman, whose weight had reached 295 pounds, following an operation upon the hypophysis eight years earlier; a young woman suffering from "Dercum's" disease; a middle aged woman, five feet two inches tall, whose weight had reached 420 pounds.

We found that departures from the predicted weight were always accounted for by storage or loss of water. Our data permit the conclusion that obese individuals oxidize body tissues in amounts precisely required to make up the caloric deficit of the diet.

The application of this principle to the undernourished normal subject is shown in figure 5. The broken line represents the predicted loss of weight; the solid line the actual weight, and the circles the body weight corrected each day by adding or subtracting the weight of water retained or lost during the preceding twenty-four hours. The diagram

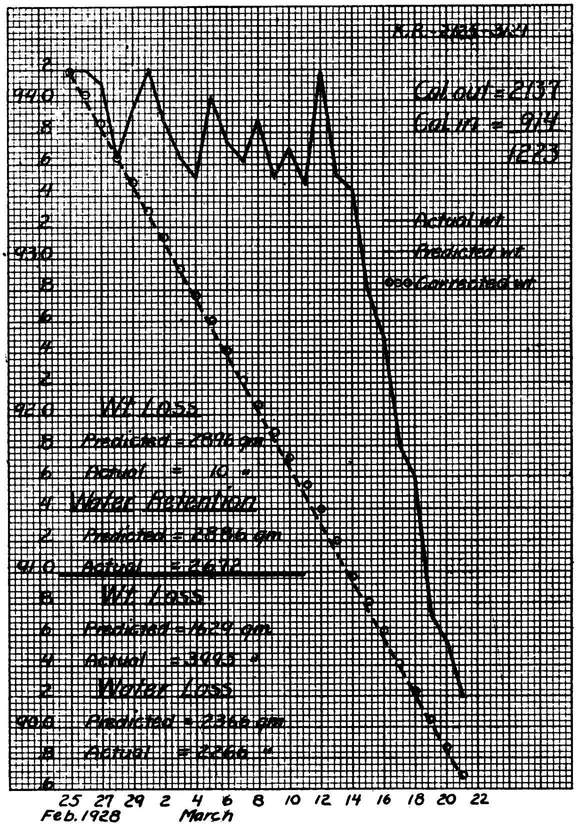

FIG. 6. OBESE SUBJECT (DISEASE OF HYPOPHYSIS) DURING UNDERNUTRITION

Actual daily weight corrected for retention or loss of water. The resulting figures show that the patient lost tissue in accord with the prediction.

makes it clear that the weight of the normal subject may be far from the expectation, but that the difference is solely due to water.

The data from which figure 5 was constructed are stated in table 5.

Figure 6 shows how misleading the actual weights of an obese subject who is being undernourished may be and how the correction of such weights for the aberrations of water cause them to correspond closely with those justified by the metabolic data (table 6).

The patient was a girl fourteen years of age who, as far back as she could remember, had been taller and fatter than the girls of her age. Her progress in school had always been slow and she had repeated many of the grades. Her appetite had always been excellent and she freely admitted chronic overeating. She did not enjoy physical activity but preferred sitting quietly without occupation. Menstruation had begun when she was ten years old and had been regular ever since.

TABLE 6

Diet: Protein 65; Fat 40; Carbohydrate 74; Calories 914
Total N out (daily): 11.7 grams
Calories used each 24 hours: 2137
Metabolic mixture: Protein 73; Fat 172; Carbohydrate 74
From body (daily): Protein 9; Fat 132; Water 40

Period A. Plateau

Loss of weight		Retention of water	
	grams		*grams*
Predicted	2,896	Predicted	2,886
Actual	10	Actual	2,672

Period B. Steep fall

Loss of weight		Loss of water	
	grams		*grams*
Predicted	1,629	Predicted	2, 66
Actual	3,995	Actual	2,266

She was six feet one inch tall and weighed 244 pounds when admitted to the hospital. Her tongue was exceptionally thick and broad. There was a luxuriant growth of axillary and pubic hair and the breasts were large. The basal metabolic rate was about 25 per cent below normal.

CONCLUSION

Our evidence leads to the generalization that obesity is always caused by an inflow of energy that is greater than the outflow.

Obese persons may be divided into two groups. The first group is by far the larger and in them the laying on of fat is the outcome of a perverted habit. The normal person unconsciously provides his body with stores of energy that accurately replace his energy losses. He possesses a mechanism that notifies him when he has eaten enough. At that point his desire for food ceases abruptly. The obese members of the first group, through long training, have come to require stimuli of greater intensity before they feel satisfied; or else they deliberately disregard the warning in order to continue a little longer the pleasures that come with eating. Some persons have succeeded in dulling the acuity of the sensations concerned by following the example of their overfed elders or, in fact, have been deliberately trained to overeat by their parents. Such persons are said to be suffering from hereditary obesity—a palpable fallacy. In other persons the combination of weak will and a pleasure seeking outlook upon life, lays the background for the condition. The mental make-up of these people resembles that of the chronic alcoholics.

In the second group are those persons who in the past have accurately met their energy requirements by taking in just the right amount of food, but who have entered a new state in which the utilization of energy is less than formerly. The established habit of providing the body with a fixed number of calories continues even though the requirements have fallen. The lessened outflow of energy has many causes. They may be thought of under two headings: (1) The basal metabolic rate remains normal but the total calories used are lessened because of advancing years, the acquisition of worldly goods, change of occupation, etc. (2) The basal rate becomes abnormally low as the result of myxedma or other diseases of the endocrine glands. In these persons there is also a diminution of general activity. However, adiposity does not invariably develop in this second class. It occurs commonly under these circumstances because the firmly established habit that for many years had supplied the ideal amount of energy does not change easily.

In conclusion we wish to commit ourselves to the statement that obesity is never directly caused by abnormal metabolism but that it is always due to food habits not adjusted to the metabolic requirement—either the ingestion of more food than is normally needed or the failure to reduce the intake in response to a lowered requirement.

BIBLIOGRAPHY

1. Strang, J. M., and Evans, F. A., J. Clin. Invest., 1928, vi, 277. The Energy Exchange in Obesity.
2. Lauter, S., Klin. Wchnschr., 1926, v. 1696. Über die Beziehungen zwischen energiehaushalt, wasserhaushalt und gewicht bei fettsucht.
3. Benedict, F. G., and Root, H. F., Arch. Int. Med., 1926, xxxviii, 1. Insensible Perspiration: Its Relation to Human Physiology and Pathology.
4. Johnston, M. W., and Newburgh, L. H., J. Clin. Invest., viii, 147. The Determination of the Total Heat Eliminated by the Human Being.
5. Newburgh, L. H., Johnston, M. W., and Falcon-Lesses, M., Clin. Invest., viii, 161. Measurement of Total Water Exchange.