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BY

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OF PHILADELPHIA.

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A STUDY OF THE METABOLISM OF A VEGETARIAN.

By John M. Swan, M.D.,
of Philadelphia.

(From the Laboratory of Physiological Chemistry, University of Pennsylvania.)

The patient, a student in one of the departments of the University of Pennsylvania, on whom the observations here reported were made, consulted me on March 10, 1903, complaining of a mild infection of the respiratory tract. He was then twenty years old, tall, anæmic-looking, and not at all robust in make-up. During the course of my examination I determined that the infection was not of a tuberculous nature, and learned that the patient was the son of vegetarian father and mother, and that his grandparents had also been vegetarians, as he was himself. I induced him to weigh and record the articles of his diet, to furnish me with his entire twenty-four hours' urine, and to keep a record of his body weight daily for a week. He also submitted samples of the milk that he drank, so that I might determine the amount of nitrogen that he was ingesting with this article of diet, the only animal food that he took.

From the submitted twenty-four hours' urine I determined (1) the total volume passed, (2) the amount of nitrogen excreted, with its equivalent in urea, using the Kjeldahl method, and (3) the phosphorus excretion expressed as P_2O_5, using the uranium acetate method.

From the diet lists submitted I calculated the amount of nitrogen ingested with the food as follows: The Kjeldahl method was used on five specimens of milk, thus giving an accurate estimate of the amount of nitrogen ingested with that food. From these five determinations an average was taken, and the nitrogen in the remainder of the milk used, samples of which, for one reason or another, could not be obtained, was estimated, using that average as a basis. The nitrogen-content of the other articles of diet was calculated from Atwater's tables.[1]

There are certain unavoidable inaccuracies in this study, on account of the fact that the subject was human and could not be absolutely controlled. These inaccuracies are: 1. That already referred to concerning the nitrogen-content of certain of the specimens of milk. 2. The absence of analyses of certain substances used by this individual in his diet; for instance, ginger wafers, cookies,

and other cakes, of which the subject partook freely, are all grouped in the diet lists as cake. The nitrogen factor used was that of the average of all the cake examined as given in the above-mentioned tables. Again, no analysis of peanut-butter was accessible, and the factor selected for the nitrogen in that article was that given in Atwater's tables for peanuts. Bread, toast, and rolls are all tabulated as bread, and the nitrogen factor adopted was that obtained by averaging the protein percentage in the tables for white bread and white wheat rolls. On one occasion the subject ate five cents' worth of ice-cream; this does not appear in the determinations, nor is any account taken of the nitrogen of cream chocolate, which he ate freely. 3. A third source of inaccuracy lies in the fact that the amount of nitrogen eliminated in the feces was not determined.

1. The Diet. The diet of the individual under consideration consisted in the main of white wheat bread, of rolls made of white wheat flour, with butter, potato, milk, and some form of cake. These articles he ate daily. He varied his diet by adding to it on different days celery, corn, crackers, peanut-butter, cream chocolate, apple, orange, and Graham wafers. The daily amount of nitrogen ingested with these articles determined by the methods stated above varied between 11.33 grams and 7.534 grams, corresponding to a protein ingestion of between 70.812 grams and 47.087 grams. During the week he ingested 65.396 grams, corresponding to 408.725 grams of protein, or an average of 9.342 grams daily, corresponding to 58.387 grams of protein.

The amount of protein food necessary for the proper nutritive equilibrium of man has been variously estimated by different observers. Voit, whose results have been most extensively quoted, believes that the daily diet should contain 118 grams of protein food, which is equivalent to 18.88 grams of nitrogen. Atwater,[2] whose studies have been made principally on Americans, believes 125 grams of protein food are necessary for a man doing moderate muscular work, an equivalent of 20 grams of nitrogen daily.

2. The Nitrogen Output. The nitrogen excreted in the urine varied from day to day; on some days it was greater than the amount ingested, and on other days it was less than the amount ingested. The highest excretion was 12.0204 grams; the lowest 7.476 grams; an average of 9.8192 grams per day. The total nitrogen excretion for the week was 68.735 grams, or 3.339 grams more than was ingested. If we accept 30 grams of urea as the normal output of an adult man, the equivalent in nitrogen would be 13.9 grams; if now we add something to this to allow for nitrogenous bodies other than urea, 15 grams would probably represent the normal nitrogen excretion daily; a figure considerably in excess of the amount of nitrogen excreted by the subject.

More important than this, however, is the fact that in the urine alone the subject was excreting more nitrogen than he was ingesting.

Suppose we add 0.5 gram as the nitrogen daily excreted by the feces and the sweat; then in one week the subject excreted 7.8 grams more nitrogen than he ingested—a condition of affairs not calculated to produce a robust and mentally and bodily active individual.

3. The Phosphorus Output. The phosphorus excretion (calculated as P_2O_5) varied between a maximum of 1.7303 and a minimum of 1.158; it averaged 1.5653 for the week, a quantity smaller than that which is said to be present in the normal urine. The relation of the phosphorus excretion to the nitrogen excretion was as 1 to 5.9, 1 to 7.1, 1 to 5.5, 1 to 7.7, 1 to 6.1, 1 to 6.4, and 1 to 6.1.

4. The Water Ingested and the Urine Excreted. During the week that he was under observation the subject drank 7915 c.c. water, an average of 1130.7 c.c. daily. To this must be added the water taken with the food. For example, there is about 87 per cent. water in milk, of which the subject drank 4694 c.c. during the week, in which there would be 4083.78 c.c. water. The subject, therefore, ingested more than 11,998.78 c.c. water during the week, or more than 1714.11 c.c. daily. During this period he passed 7560 c.c. urine, an average of 1080 c.c. daily. According to this calculation, 634 c.c. water must have been eliminated daily by the feces, sweat, and as vapor of water from the lungs, or some of it must have been retained in the body.

The influence of water on the metabolic processes is said by some observers to stimulate metabolic activity and to assist in washing out the products of metabolism from the tissues. (Halliburton.[3]) Others state that water increases the waste nitrogenous products (Gruber[5]), while Straub[6] found that removal of water from the food increases protein katabolism, as shown by an increase of the excretion of both nitrogen and phosphorus. Neumann, on the other hand, says that large quantities of water have no influence on metabolism other than to flush out the products of katabolism.

5. The Weight. By a reference to the table it will be seen that the weight of the individual who was the subject of this study varied between a maximum of 65.3 kilograms (144 pounds) and a minimum of 64.5 kilograms (142¼ pounds).

It is admitted by everyone that nitrogen is essential for the maintenance of human life and metabolic activity. The questions in dispute are: 1. Whether the nitrogen contained in vegetable food is as valuable as an element of nutrition as that contained in animal food, particularly in meat. 2. Whether the bodily functions of an individual using vegetable nitrogen exclusively are conducted in a normal manner. 3. The amount of nitrogen required daily by a human subject for the best results of growth and of bodily and mental function. It has been claimed by some (Davis[7]) that the protein contained in vegetable food is less easily digested than that of meat; this has been denied by others. The probability is that the protein itself is just as easily digested if it come from one

source as from the other; but that the proportion of protein, bulk for bulk, renders that contained in animal food more readily available.

In this connection, some experiments made by Rockwood[9] are of interest. He found that vegetable proteins are not utilizable to the same extent as those of animal origin, unless they are removed from the materials associated with them. The degree of utilization, however, is found to be slightly increased by long cooking. In one experiment extracted vegetable protein showed itself capable of as great utilization as that of animal protein; in another experiment less so.

The strict vegetarian must take a large bulk of vegetable food in order to obtain the quantity of protein required for the needs of his tissues. The large quantity of carbohydrate ingested in order to procure the necessary protein must be a hindrance to normal body chemistry, on account of the fermentations that are likely to take place in the intestinal tract. Writers seem to be agreed that the use of a strictly vegetable diet, while it may permit of a normal amount of work at times, will not permit of sustained effort, nor will it allow users to meet sudden calls for increased exertion. Furthermore, it has been shown that strict vegetarians lose vigor, become languid, and are not inclined to do severe mental and physical work (Davis,[7] Parkes,[4] Halliburton[3]).

In the case under review the anæmic and delicate appearance of the subject, together with the fact that his college work was below the average of efficiency, would point to a deficient diet, although the influence of other possible causes have not been overlooked.

The amount of nitrogen required by the human subject in twenty-four hours for the best performance of body function is variously estimated: According to Moleschott, 130 grams of protein, equivalent to 20.8 grams of nitrogen; according to Ranke, 100 grams of protein, equivalent to 16 grams of nitrogen; according to Voit, 118 grams of protein, equivalent to 18.88 grams of nitrogen; according to Forster, 131 grams of protein, equivalent to 20.96 grams of nitrogen; according to Atwater,[1] 125 grams of protein, equivalent to 20 grams of nitrogen, are required daily. Halliburton[3] places the necessary daily nitrogen at 15 grams. Sivén[8] found, however, that for a short time an adult, without increasing the total heat value of the food beyond the normal, can remain in nitrogen equilibrium and good working condition with an income of nitrogen of only 4.52 grams, or 28.25 grams of protein. We may assume, in spite of this abnormally low figure, that between 15 and 20 grams of nitrogen, corresponding to 93.75 to 125 grams of protein, are required daily by a man doing ordinary work. The subject of this study was taking much less than the minimum requirement.

Conclusions. 1. A male, aged twenty years, took habitually a diet composed of white wheat bread or rolls made of white wheat

flour, with butter, potato, some form of cake, celery, corn, crackers, peanut-butter, cream chocolate, apple, orange, Graham wafers, and milk, the last being his only article of food of animal origin. By the use of this diet he ingested an average of 9.342 grams of nitrogen daily, corresponding to 58.387 grams of protein. During the period of observation he excreted in his urine an average of 9.8192 grams of nitrogen daily, equivalent to 21.032 grams of urea daily. During the entire period he excreted 3.339 grams more nitrogen in his urine than he ingested with his food. He excreted an average of 1.5653 grams of P_2O_5 daily. He ingested an average of 1130.7 c.c. of water daily, to which the addition of the water in the milk drunk would bring the daily average of water taken to 1714.11 c.c. He passed an average of 1080 c.c. of urine daily. His weight was maintained between 64.5 kilograms (142¼ pounds) and 65.3 kilograms (144 pounds).

2. The study of the patient seems to show that, for this individual at least, the diet was not calculated to produce a properly nourished and mentally and bodily active individual. There are undoubtedly strong and robust individuals who live on a very simple diet; but I believe that such are the exception rather than the rule. The average book, pamphlet, or magazine article advocating vegetarianism, so far as I have been able to examine such, contains no accurate scientific analysis of the requirements of the human organism, and the arguments advanced for the adoption of such a regimen are pseudo-scientific or sentimental.

March 15, 1903.

Diet.	Weight in grams.		Nitrogen in diet.
Bread	119	Bread	3.121
Potato	127	Potato	0.548
Cake	127	Cake	1.422
Celery	14	Celery	0.031
Corn	92	Corn	0.413
Gingerbread	10	Gingerbread	0.086
Crackers	49	Crackers	0.768
Peanut-butter	35	Peanut-butter	1.448
Milk*	701	Milk*	3.493
Butter	31		
		Total	11.330

March 16, 1903.

Diet.	Weight in grams.		Nitrogen. in diet.
Bread	205	Bread	1.442
Potato	297	Potato	1.283
Crackers	35	Crackers	0.548
Peanut-butter	21	Peanut-butter	0.866
Cake	56	Cake	0.627
Butter	42	Milk*	3.989
Milk*	785		
		Total	8.755

* Nitrogen in milk determined from averages of actual analyses.

March 17, 1903.

Bread	235	Bread	3.684
Potato	241	Potato	1.041
Crackers	35	Crackers	0.548
Peanut-butter	21	Peanut-butter	0.866
Cake	49	Cake	0.548
Cream chocolate	28	Milk†	3.882
Butter	63		
Milk†	779	Total	10.569

March 18, 1903.

Bread	205	Bread	3.214
Potato	191	Potato	0.825
Crackers	50	Crackers	0.784
Peanut-butter	28	Peanut-butter	1.154
Cake	49	Cake	0.548
Cream chocolate	49	Milk†	3.075
Butter	56	Milk*	1.366
Milk†	617		
Milk*	283	Total	10.966

March 19, 1903.

Bread	262	Bread	4.111
Potato	142	Potato	0.613
Cake	70	Cake	0.784
Orange	36	Orange	0.046
Cream chocolate	71	Milk*	1.190
Butter	70	Milk†	1.520
Milk*	233		
Milk†	305	Total	8.264

March 20, 1903.

Bread	226	Bread	3.543
Potato	312	Potato	1.347
Graham wafers	21	Graham wafers	0.329
Cake	42	Cake	0.470
Apple	135	Apple	0.108
Butter	49	Milk*	2.181
Milk*	432		
		Total	7.978

March 21, 1903.

Bread	213	Bread	3.339
Potato	163	Potato	0.704
Cake	63	Cake	0.705
Cream chocolate	149	Milk†	2.786
Butter	42		
Milk†	559	Total	7.534

* Nitrogen in milk determined by Kjeldahl's method.
† Nitrogen in milk determined from averages of actual analyses.

Date.	Nitrogen in diet.	Protein in diet.	Nitrogen in urine.	Equivalent in urea.	Water ingested.	Water ingested as milk.	Urine passed.	P_2O_5 excreted.	Weight.
March 15	11.330	70.812	10.395	22.275	1500 c.c.	609.87 c.c.	1650 c.c.	1.749	64.8 k. (142¾ lbs)
" 16	8.755	54.718	9.2046	19.7242	907 "	682.95 "	1105 "	1.2818	64.8 k. (142¾ lbs)
" 17	10.569	66.056	9.5711	20.5095	985 "	677.73 "	1210 "	1.7303	64.8 k. (142¾ lbs)
" 18	10.966	68.537	12.0204	25.7580	1155 "	783.00 "	1080 "	1.674	64.5 k (142¼ lbs)
" 19	8.264	50.650	10.6543	22.8307	998 "	468.06 "	1095 "	1.7191	65.3 k. (144 lbs)
" 20	7.978	49.862	7.476	16.02	1071 "	375.84 "	600 "	1.158	64.8 k. (142¾ lbs)
" 21	7.534	47.087	9.4136	20.172	1299 "	486 33 "	820 "	1.5252	64.9 k. (143 lbs)
Total	65.396	407.722	68.735	147.2694	7915 "	4083.78 "	7560 "		

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