

# CLINICAL CALORIMETRY

## XXIX. THE METABOLISM IN TUBERCULOSIS \*

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### INTRODUCTION

In regard to the dietary of tuberculous patients medical opinion has fluctuated within wide limits. The extent of this fluctuation may be seen by an examination of the data collected by Fisher,<sup>1</sup> regarding the dietaries given patients by ninety-five of the leading sanatoriums of the world. In this list the total number of calories fed daily ranges from a maximum of 5,500 to a minimum of 2,140. The number of grams of protein varies from 60 to 190 per diem. To the practical physician, who is faced with the problem of selecting the best type of dietary to prescribe for tuberculous patients, the problem is quite bewildering. To make the selection it is necessary to know, first, the total energy transformations in such patients and, second, the extent of destruction of protein by the toxins of the disease and the minimum amount of protein which must be given to maintain the patient in nitrogen equilibrium. A search of the literature for this information yields unsatisfactory results because of the meagerness of the data and of the fact that most of the work was done before the advent of the most accurate methods of study.

### HISTORICAL

For a very complete and comprehensive compilation of the work done prior to 1903 one may refer to Ott.<sup>2</sup> A great part of this work, in which it appears that the technic used was crude and experimental conditions poorly controlled, will be omitted in our references. Some of it is of great historical interest, as for instance, the work of Nysten<sup>3</sup> carried out in Paris in 1811. By means of a respiratory valve he separated the inspired from the expired air, which he collected in a bladder during a measured period of time. This air was analyzed

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\* From the Russell Sage Institute of Pathology in affiliation with the Second Medical Division of Bellevue Hospital.

† During 1916-1917 Dr. Wm. H. Olmstead of St. Louis assisted in the work.

1. Fisher, Irving: Proc. Sixth Internat. Congr. on Tuberculosis **1**:694, Part 2, 1908.

2. Ott, A.: Die chemische Pathologie der Tuberculose, Berlin, 1903.

3. Nysten: Ueber die chemischen Atmungserscheinungen in Krankheiten, Meckel's Deutsch. Arch. f. Physiol. **3**:264, 1817.

for carbon dioxide by shaking it with lime water (over mercury in a graduated cylinder), the oxygen then being absorbed by phosphorus. Calculation of the energy transformation from the gaseous exchange could not be done at that time, but the physiologic principle is the one most commonly used today. This work is most significant when one considers that it was contemporary with the development of percussion of the chest by Auenbrugger, and the invention of the stethoscope by Laennec.

Although the physical diagnosis of the disease progressed by leaps and bounds, the next study of the respiratory exchange was not made until by Hannover,<sup>4</sup> who studied the production of carbon dioxide in five patients with phthisis. The body weight is given and the carbon dioxide per minute. By assuming an average respiratory quotient of 0.80, we may calculate the daily heat production of these patients as between 1,200 and 2,100 calories per day, and from 26.5 to 40 calories per kilogram of body weight. In 1878 Moeller<sup>5</sup> studied three poorly nourished patients with phthisis, males weighing from 44 to 45 kg., aged from 24 to 48 years. The carbon dioxide produced was measured in the Pettenkoffer-Voit apparatus in six hour periods. These patients all had food and beer, so that the metabolism was not basal. Assuming an average respiratory quotient of 0.80, the daily heat production would be between 1,600 and 1,780 calories, or from 35 to 40 calories per kilogram of body weight.

The first work in which the finding of normal respiratory quotients may be taken as evidence of good technic is that of Loewy,<sup>6</sup> who studied exchange of oxygen and carbon dioxide, minute volume respired and nitrogen excretion at different body temperatures after tuberculin injections, using the Zuntz-Geppert apparatus. He found that there was only a moderate increase in oxygen consumption in fever and that it was greater with rising than with falling temperatures. In three of his cases, which were incipient, the minute volume respired increased slightly, but in a fourth case with extensive tuberculosis there was a rather close parallelism between the oxygen consumed and the minute volume. This observation is one of extreme practical importance, as will be seen later.

In the same year Kraus and Chvostek<sup>7</sup> studied five phthisical patients with a Zuntz-Geppert apparatus. In some of the cases the

4. Hannover: *De quantitate relativa et absolute acidi carbonici ab homine sano et aegroto exhalati*, Copenhagen, 1845, p. 82.

5. Moeller: *Kohlensäureausscheidung der Menschen bei verkleinerter Lungenoberfläche*, *Ztschr. f. Biol.* **14**:542, 1878.

6. Loewy, A.: *Stoffwechseluntersuchungen im Fieber und bei Lungenaffectationen*, *Virchow's Arch. f. path. Anat.* **126**:218, 1891.

7. Kraus and Chvostek: *Ueber den respiratorischen Gaswechsel im Fieberanfall nach Tuberculininjection*, *Wien. klin. Wchnschr.* **4**:104, 127, 1891.

respiratory quotients lie beyond the limits of possibility. These are the first investigators to give the height of the patient so that the surface area may be calculated. The conditions were not basal, as the patient was not fasting. However, calculations show that an increase of 39 per cent. in the metabolism increased the minute volume respired from 7,743 c.c. to 10,000 c.c., in a case in which proper quotients were obtained.

Work done by Speck<sup>8</sup> may be mentioned also, since it shows in many cases a marked parallelism between the amount of carbon dioxide produced and the minute volume. The respiratory quotients are either so low or so high as to make the results of doubtful value. Data relative to the amount of food taken and muscular activity are not given. Robin and Binet<sup>9</sup> give mass statistics regarding the minute volume, lung capacity, oxygen consumption and respiratory quotients of 162 phthisical patients. Averages only are given, the methods used are not stated, and there has been no attempt to compare individual patients with normals of the same size, so that the data are not very satisfactory. However, it is of interest to note that the minute volumes respired were from 80 to 110 per cent. greater than those of the normals studied. They also found a consumption of oxygen from 70 to 100 per cent. greater. The respiratory quotients were lower in the tuberculous patients. Lung capacity was also greatly reduced.

Stachelin<sup>10</sup> studied a tuberculous patient during a night sweat in a Jacquet respiration chamber. Food was taken before the observation and the subject was very restless. He concluded, however, that the metabolism was not raised and that sweating had no influence on the total metabolism.

In a recent study of the effect of acetyl salicylic acid on the heat regulation in fever Barbour<sup>11</sup> used three tuberculous subjects. These subjects were studied in a Benedict respiration chamber under basal conditions. The basal metabolism in these three cases was only from 3 to 4 per cent. above the average normal.

The absorption of food in tuberculosis has been studied by Blumenfeld,<sup>12</sup> who found that the percentage losses of nitrogen and fat in the stools were within normal limits. However, in certain cases there was marked interference with absorption. Biedert<sup>13</sup> reported a case

8. Speck: *Physiologie des menschlichen Athmens*, 1892.

9. Robin and Binet: *Bull. méd. Par.* **15**:249, 1901.

10. Stachelin, R.: *Der respiratorische Gaswechsel eines Phthisikers während des Nachtschweisses*, *Ztschr. f. klin. Med.* **66**:241, 1908.

11. Barbour, Henry G.: *Arch. Int. Med.* **24**:624 (Dec.) 1919.

12. Blumenfeld, F.: *Ueber die diaetetische Verwerthung der Fette bei Lungentuberculose*, *Ztschr. f. klin. Med.* **28**:417, 1895.

13. Biedert: *Die Tuberculose des Darms und des lymphatischen Apparats*, *Jahr. f. Kinderh.* **21**:172, 1884.

TABLE 1.—ALCOHOL CHECKS FOR 1916-17

Date and Per Cent. of Alcohol by Weight	Hour	Alcohol Burned, Gm.	Heat		Oxygen		Carbon Dioxide		Water		R. Q. Theory 0.667
			Theory, Cal.	Found, Cal.	Theory, Gm.	Found, Gm.	Error, per Cent.	Theory, Gm.	Found, Gm.	Error, per Cent.	
5/17/16 92.92	1	13.49	87.63	87.20	25.80	26.35	23.65	23.34	15.47	16.09	+4.0
	2	13.26	87.23	87.41	25.69	24.75	23.34	23.34	15.40	15.91	+3.3
	3	13.72	90.26	89.24	26.58	26.29	24.36	23.90	15.93	16.26	+2.1
Average	...	.....	88.37	87.94	26.02	25.80	23.85	23.59	15.60	16.09	+3.1
10/3/16 92.92	1	12.05	79.27	82.92	23.34	23.31	21.40	21.42	13.99	15.14	+8.2
	2	12.78	84.07	86.45	24.76	25.05	22.69	22.57	14.84	15.76	+6.2
Average	...	.....	81.67	84.24	24.05	24.18	22.05	22.00	14.42	15.45	+7.2
10/10/16 92.92	1	12.83	84.41	83.51	24.85	24.93	22.78	22.42	14.90	15.27	+2.5
	2	13.16	86.57	87.08	25.49	24.94	23.37	23.42	15.28	15.79	+3.3
	3	13.36	87.89	85.42	25.88	25.88	23.72	23.39	15.51	15.76	+1.6
Average	...	.....	86.29	85.34	25.41	25.25	23.29	23.08	15.23	15.61	+2.5
12/4/16 92.92	1	11.97	78.75	80.57	23.19	22.63	21.25	20.92	13.40	31.40	-7.4
	2	11.68	76.84	77.80	22.63	22.37	20.74	20.78	33.57	30.89	-8.0
	3	11.33	74.54	76.88	21.95	21.21	20.12	19.67	33.16	30.63	-7.6
Average	...	.....	76.71	78.42	22.59	22.07	20.70	20.46	33.54	30.97	-7.2
2/28/17 92.44	1	11.94	78.14	78.15	23.01	22.66	21.09	20.61	13.85	14.39	+3.9
	2	11.91	77.95	78.32	22.95	22.18	21.04	21.09	13.83	13.62	-1.5
	3	12.12	79.82	80.64	23.36	23.13	21.41	21.19	14.06	14.37	+2.2
Average	...	.....	78.47	79.04	23.11	22.66	21.18	20.96	13.91	14.13	+1.6
4/23/17 92.44	1	12.62	82.59	82.93	24.32	23.01	22.92	21.47	14.64	14.58	-0.4
	2	11.39	74.94	75.36	21.95	21.65	20.12	20.12	13.82	13.82	0.0
	3	13.40	87.70	87.98	25.82	46.92	23.67	43.92	13.35	15.45	+1.8
Average	...	.....	81.61	82.09	24.03	23.31	22.03	21.46	14.47	14.62	+0.6
Totals	.....	.....	1397.70	1406.96	411.57	405.61	377.25	372.45	307.10	305.14	-0.6

\* 20 gm. extra water introduced.

of fat diarrhea in a child with tuberculosis of the intestine, mesenteric lymph nodes and peritoneum. Also Friederich Mueller<sup>14</sup> found a loss of 32.9 per cent. of fat and 7.9 per cent. of nitrogen in the stools of a patient with tuberculous ulcers in the intestine and marked amyloidosis which involved the liver very slightly and the pancreas not at all.

The question of the toxic destruction of protein has received much attention. An excellent compilation of this work, with abundant quotations of experimental data, may be found in Ott.<sup>2</sup> The general results of this work tend to show that in the afebrile condition many phthisical patients will readily make large gains in nitrogen. With febrile patients, either with spontaneous fever or with fever following tuberculin injections, small losses of nitrogen occur on diets furnishing about 2,500 calories and from 100 to 150 gm. of protein per diem. These small nitrogen losses would become important only because of the long duration of the disease. The determination of the protein minimum in tuberculosis does not seem to have been made, although it has been the subject of some speculation.

The discussion of the nitrogen losses in phthisis would be incomplete without mention of loss in the sputum. Lanz<sup>15</sup> estimated the daily nitrogen loss in the sputum of sixteen patients with phthisis. The protein loss was calculated from the total nitrogen of the sputum and varied from 1.69 to 7.00 gm. of protein per diem.

#### METHODS OF STUDY

The respiration calorimeter of the Russell Sage Institute of Pathology was employed. This apparatus has been previously described in Paper 2 of this series.<sup>16</sup> The technic has been essentially that described in Paper 4 of the series,<sup>17</sup> with the few exceptions noted below. Patients were studied 14 to 16 hours after the last regular meal, though each received the small standard breakfast described in Paper 26 of this series.<sup>18</sup> The only effect of this meal was found to be an increase in the metabolism of 2 per cent. in the third hour

14. Mueller, Fr.: Untersuchungen über Icterus, *Ztschr. f. klin. Med.* **12**:86, 1887.

15. Lanz: *Deutsch. Arch. f. klin. Med.* **56**:619, 1896.

16. Riche, J. A., and Soderstrom, G. F.: The Respiration Calorimeter of the Russell Sage Institute of Pathology in Bellevue Hospital, *Arch. Int. Med.* **15**:805 (June) 1915.

17. Gephart, F. C., and Du Bois, E. F.: The Determination of the Basal Metabolism of Normal Men and the Effect of Food, *Arch. Int. Med.* **15**:835 (June) 1915.

18. Soderstrom, G. F., Barr, D. P., and Du Bois, E. F.: The Effect of a Small Breakfast on the Heat Production, *Arch. Int. Med.* **21**:613-620 (May) 1918.

TABLE 2.—ALCOHOL CHECKS FOR 1919-20

Date and Per Cent. of Alcohol by Weight	Hour	Alcohol Burned, Gm.	Heat		Oxygen		Carbon Dioxide		Water		R. Q. Theory 0.667
			Theory, Cal.	Found, Cal.	Theory, Gm.	Found, Gm.	Error, per Cent.	Theory, Gm.	Found, Gm.	Error, per Cent.	
12/5/19 86.4	1	12.87	81.45	81.16	23.99	23.85	21.99	21.62	14.86	15.18	+2.2
	2	12.63	79.30	81.48	23.31	23.31	21.40	21.40	14.47	14.46	+0.4
	3	12.63	79.91	79.83	23.53	22.93	21.57	21.35	14.58	14.92	+2.3
	4	12.64	80.00	77.78	23.56	23.02	21.59	20.77	14.60	14.90	+2.1
Average	...	...	80.17	80.06	23.61	23.28	21.64	21.26	14.63	14.99	+2.5
2/26/20 86.4	1	11.15	70.54	71.91	20.77	19.96	19.04	18.54	13.87	13.22	+2.7
	2	10.84	68.98	68.14	20.19	21.39	18.51	17.74	13.52	12.73	+1.7
	3	11.21	70.95	71.75	20.89	20.45	19.15	18.65	12.95	13.28	+2.5
Average	...	...	70.02	70.60	20.62	20.60	18.90	18.31	12.78	13.08	+2.3
2/28/20 86.4	1	10.98	69.47	69.11	20.45	20.30	18.75	18.08	12.68	13.58	+7.1
	2	10.67	67.52	68.38	19.88	20.14	18.22	17.21	12.32	13.32	+8.1
	3	10.31	65.23	66.57	19.21	19.02	17.61	16.47	11.90	12.94	+8.7
Average	...	...	67.41	68.02	19.85	19.82	18.19	17.25	12.30	13.28	+8.0
3/15/20 86.4	1	11.66	78.81	74.30	21.73	19.22	19.67	19.67	13.47	14.07	+4.5
	2	11.31	71.56	71.29	21.07	20.44	19.31	18.92	13.06	13.30	+1.8
	3	11.15	70.56	71.90	20.78	21.03	18.74	18.74	12.88	13.63	+5.8
	4	11.19	70.80	71.13	20.84	20.80	19.11	18.54	12.92	13.34	+3.3
Average	...	...	71.68	72.16	21.11	20.37	19.35	18.97	13.08	13.59	+4.0
3/18/20	1	11.70	72.96	75.22	21.48	21.25	19.60	19.47	13.49	13.84	+2.6
	2	12.64	78.50	82.69	23.20	22.35	21.27	20.85	14.57	15.11	+3.7
3/22/20 88.1	1	12.23	78.22	80.18	22.44	22.20	20.57	20.34	14.00	14.60	+3.6
	2	12.27	76.51	79.60	22.53	22.19	20.65	20.00	14.15	14.68	+3.6
	3	12.27	76.51	79.60	22.53	22.19	20.65	20.00	14.15	14.68	+3.6
Average	...	...	77.18	80.82	22.72	22.25	20.83	20.43	14.27	14.79	+3.6
5/6/20 88.1	1	12.27	76.52	77.41	22.53	22.24	20.66	20.11	14.15	14.64	+3.5
	2	11.89	74.15	74.88	21.83	21.21	20.01	19.40	13.71	14.29	+4.2
	3	11.88	74.09	75.64	21.82	21.76	20.00	19.67	13.70	14.29	+4.3
Average	...	...	73.92	75.98	22.06	21.73	20.22	19.76	13.85	14.41	+4.0
Totals	.....	.....	1543.94	1570.35	458.07	449.06	418.06	407.60	283.94	298.80	+5.2

after eating. As a rule the observations were started in the latter part of the third hour or early in the fourth hour.

In the direct calorimetric calculation of the heat lost from or stored in the body, the rectal temperature was used, taking the specific heat only of the body at 0.83. This figure has been found to give fairly accurate results in a considerable series of normal subjects. At best, however, it can be considered as merely an average figure. For different individuals it must vary considerably, depending on the proportions of the various tissues in the body, especially of fat (specific heat = 0.45) and water (specific heat = 1).<sup>19</sup> Moreover, even though the specific heat is not known exactly, it may be considered to remain constant during short periods. The body weight for short periods is likewise a constant. With this in view, a comparison in each hour of the heat production (calculated from the respiratory exchange) with the heat elimination (measured directly) will show that the change in the rectal temperature does not always parallel that of the average body temperature.

The surface area in each case was determined from the height and weight by the "height-weight chart" of Du Bois and Du Bois.<sup>20</sup> In calculating the variations of the metabolism from the average normal, based upon the surface area, the normal heat production per square meter of body surface has been taken from the table given by Aub and Du Bois,<sup>21</sup> which takes into account the effect of age. If the predictions of the normal metabolism for each individual in the series based upon the figures of Aub and Du Bois are compared with the predictions for the same individuals made from Benedict's tables<sup>22</sup> the average difference between the two predictions will be found to be about 3 per cent.

#### ALCOHOL CHECKS

Interspersed throughout the series were a number of alcohol checks. The first four cases of the series were studied in 1917. The alcohol checks for that period are to be found in Table 1. As the calorimeter had not been in use during the war it was necessary to make quite a number of checks before the apparatus was finally put in good condition. A satisfactory check was first obtained on Dec. 5, 1919, so

19. Rubner, M.: *Kalorimetrie*, Tigerstedt's *Handb. d. physiologische Methoden*, Hirzel, Leipzig, 1911, 1:170, Part. 3.

20. Du Bois, Delafield, and Du Bois, E. F.: A Formula to Estimate the Approximate Surface Area if Height and Weight be Known, *Arch. Int. Med.* **17**:863 (June) 1916.

21. Aub, J. C., and Du Bois, E. F.: The Basal Metabolism of Old Men, *Arch. Int. Med.* **19**:823 (June) 1917.

22. Harris, J. A., and Benedict, F. G.: A Biometric Study of the Basal Metabolism in Man, *Carnegie Int. Wash.*, 1919, Pub. 279.

that patients were not studied until after that date. The results of the alcohol checks for 1919-1920 are given in Table 2.

During all of the previous work with the calorimeter a special soda lime was used.<sup>23</sup> This same soda lime was used up to Feb. 12, 1920. At this time a new soda lime, which had been devised for use in submarines, was introduced. This product contained relatively little sodium hydroxid and, consequently, the water formed in the reaction with carbon dioxid was not held in the soda lime but passed off rapidly into the sulphuric acid of the last absorber in the train. The efficiency of this latter absorber was not great enough to handle all of this moisture. The result is seen in examining the alcohol checks for February 26 and 28, and March 15. In these checks the carbon dioxid found was too low, while the results for oxygen consumed and for heat check fairly well. The effect of this error is to give respiratory quotients which are too low. The results for the direct calorimetry are quite satisfactory, and the error in the indirect calorimetry is small, since the indirect calculation is based on the oxygen, for which better checks were obtained.

After March 15, 1920, the Stanley Jordan soda lime was again used, the checks for March 18 and 22 being satisfactory for the purpose of this study.

#### REPORT OF CASES<sup>24</sup>

##### CASE 1.—Charles G. *Tuberculosis of pleurae and peritoneum.*

*History.*—A laborer, 31 years of age, born in the United States, was admitted to the service of Dr. Charles Nammack in Bellevue Hospital April 13, 1917, and discharged unimproved June 3, 1917.

September, 1916, he had pleurisy with effusion on the left side. March 12, 1917, he began to feel pain, localized to a small area in the epigastrium. He had much flatulence. Five days later he noticed that his abdomen was swollen. He had been constipated and the pain had steadily increased in intensity. He had severe night sweats but no cough.

*Physical Examination.*—Patient was a poorly developed, emaciated negro; height 165 cm.; weight 52.4 kg. The tongue showed a white coat. There were signs of fluid on the right side of the chest to one inch below the spine of the scapula and, on the left, to the angle of the scapula. There was harsh breathing, with many râles above the level of the fluid. The heart was overacting. The rate was rapid, 120 or more, when the patient was in dorsal decubitus. The abdomen was tense and offered a boggy resistance to palpation. There was dulness in both flanks and a distinct fluid wave.

*Laboratory Examination.*—Urine showed a trace of albumin, hyaline and granular casts. The sputum was examined but no tubercle bacilli were found. Usually his cough was unproductive. The roentgenogram showed pleural effusion on both sides, but no lung involvement.

April 14, in the general ward, the abdomen was tapped and 3,800 c.c. of cloudy, blood-tinged fluid were removed. A guinea-pig, injected with this

23. Made by the Stanley Jordan Company, New York.

24. The first four cases were studied by D. P. Barr in 1917; the remainder by W. S. McCann in 1919-1920.

fluid, died of intercurrent infection April 30, showing no sign of tuberculosis. April 23 the right chest was tapped and 1,500 c.c. of cloudy, straw-colored fluid were removed.

May 7 he was admitted to the metabolism ward. He was observed in the calorimeter May 8, 11 and 14. With temperature varying from 37.8 to 38.1 C., his basal metabolism was 13 per cent. above the average normal. His right chest was tapped a second time May 15 and 400 c.c. of thick, bloody fluid were withdrawn. While in the ward he ran a remittent temperature. The symptoms remained unchanged. He maintained his weight and had an excellent appetite. June 3 he was discharged unimproved.

TABLE 3.—DIET CHART AND NITROGEN BALANCE IN CASE 1

Name and Date	Food			Food N, Gm.	Urine N, Gm.	Feces N, Gm. (Estimated)	Excreta N, Gm.	N Balance, Gm.	Body Weight, Kg.
	Total Calories	Carbohydrate, Cals.	Fat, Cals.						
Charles G.									
5/ 8/17	2,247	925	981	13.3	12.5	1.3	13.8	-0.5	53.1
5/ 9/17	2,233	967	889	14.7	11.2	1.5	12.7	+2.0	
5/10/17	2,179	908	909	14.1	11.2	1.4	12.6	+1.5	52.5
5/11/17	2,225	860	1,006	14.0	12.5	1.4	13.9	+0.1	
5/12/17	2,668	1,017	1,257	15.4	13.4	1.5	14.9	+0.5	
5/13/17	2,733	1,110	1,229	15.4	13.5	1.5	15.0	+0.4	53.5
5/14/17	1,575	636	686	10.0	9.0	1.0	10.0	0.0	
5/15/17	2,639	1,159	1,082	15.5	13.6	1.6	15.2	+0.3	53.7
5/16/17	2,614	1,057	1,166	15.3	11.9	1.5	13.4	+1.9	
5/17/17	1,580	899	595	3.4	8.3	1.0	9.3	-5.9	53.0
5/18/17	2,637	1,383	1,167	3.4	8.3	1.0	9.3	-5.9	53.2
5/19/17	2,635	1,280	1,288	3.4	4.9	1.0	5.9	-2.5	53.7
5/20/17	2,575	1,269	1,221	3.3	4.5	1.0	5.5	-2.2	52.4
5/21/17	2,548	1,261	1,211	3.0	5.0	1.0	6.0	-3.0	52.7
5/22/17	2,400	1,061	1,255	3.3	5.1	1.0	6.1	-2.8	52.8
5/23/17	2,091	947	1,072	2.8	4.3	1.0	5.3	-2.5	52.2
5/24/17	2,635	1,114	1,136	15.0	8.2	1.5	9.7	+5.3	52.5
5/25/17	2,875	1,482	1,300	3.6	5.9	1.0	6.9	-3.3	52.6
5/26/17	2,973	1,705	1,189	3.1	5.2	1.0	6.2	-3.1	52.6
5/27/17	2,951	1,690	1,185	3.0	4.4	1.0	5.4	-2.4	52.7
5/28/17	2,725	1,421	1,224	3.1	4.8	1.0	5.8	-2.7	52.9
5/29/17	3,167	1,950	1,142	2.9	4.7	1.0	5.7	-2.8	52.1
5/30/17	3,138	1,886	1,178	2.9	4.7	1.0	5.7	-2.8	52.4
5/31/17	3,019	1,826	1,106	3.4	5.0	1.0	6.0	-2.6	52.1
6/ 1/17	2,905	1,570	1,260	2.9	4.9	1.0	5.9	-3.0	

CASE 2.—Trellis H. *Tuberculosis of lungs and lymph nodes.*

*History.*—A waiter, 24 years of age, born in the United States, was admitted to the service of Dr. Robert J. Carlisle May 3, 1917, and discharged unimproved May 22, 1917. The history was not satisfactory because of the very limited intelligence of the patient. In 1913 he had empyema, for which he was treated at the Presbyterian Hospital in Chicago.

April 15 he noticed for the first time a mass beneath the chin on the left side, which grew rapidly. About two weeks later he found that a similar, smaller mass had appeared on the right side. He had had an occasional dry, tickling cough, but no night sweats.

*Physical Examination.*—Patient was a poorly developed, poorly nourished boy, mentally deficient, height 168 cm., weight 51.6 kg. The teeth showed a marked pyorrhea and were in very bad condition. In the submental region and at the angles of the jaw there were large, hard, semi-elastic, painless masses. The swelling at the angle of the jaw on the right side was hot and showed slight fluctuation. There was a chain of very hard, discrete glands in the right groin; another of similar character in the left axilla.

*Lungs:* At both apices anteriorly and posteriorly there was dulness to percussion. There was high pitched, almost tubular breathing over the left apex posteriorly and there were a few subcrepitant râles over the right apex.

*Laboratory Examination.*—The urine was negative. Blood: Leukocytes, 8,200; polymorphonuclears, 69 per cent.; erythrocytes, 4,400,000; hemoglobin, 75 per cent. Wassermann negative. Von Pirquet positive. The roentgenogram showed marked peribronchial infiltration in the left upper lobe between the first and third ribs. The sputum was repeatedly examined, but no tubercle bacilli were found.

May 9: Basal metabolism, with temperature from 40.1 to 40.2 C., was 29 per cent. above the average normal, and with temperature between 39.7 and 40.1 C., it was 43 per cent. above the average normal, due, in part, to coughing.

His condition did not change while in the hospital. His temperature was irregular. May 22 he was transferred to a tuberculosis sanitarium.

CASE 3.—Robert W. *Pleurisy with effusion.*

*History.*—A ship's carpenter, 39 years of age. He was admitted April 23, 1917, and discharged improved on June 2, 1917. He had been in the Navy for eight years. For the past six years he had been on mercantile vessels. In 1900 he had pneumonia, with which he was ill for one month. He had always been a very heavy drinker. He denied venereal disease.

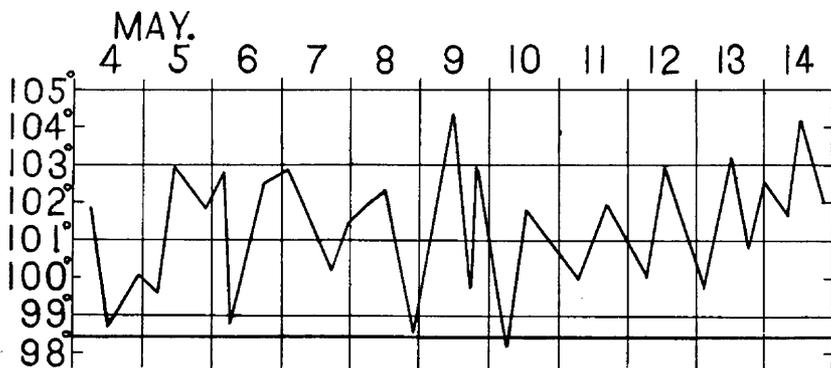


Fig. 1.—Temperature chart of Trellis H.

April 13 he began to feel short of breath, coughed frequently and had some pain in the epigastrium and along the sternum. Coughing or deep breathing increased the pain.

*Physical Examination.*—Patient was a well developed, rather emaciated man who showed a moderate degree of cyanosis, height 165 cm.; weight 53.4 kg. Lungs: There was absence of fremitus, flatness on percussion, distant voice and distant bronchovesicular breathing over the entire left lung. The right lung was normal. Heart: Was pushed to the right. The right border was 8 cm. to the right of the midsternal line. The left border of dullness merged with flatness of fluid. Coughing was unproductive.

*Physical Examination.*—One sample of sputum was obtained, but contained no tubercle bacilli. Urine: negative. Blood: Leukocytes, 8,400; polymorphonuclears, 64 per cent.; lymphocytes, 27 per cent. Roentgenogram showed pleurisy with effusion on the left side, but indicated no lung involvement.

April 24, 1,400 c.c. of straw-colored fluid were removed from the left chest. No tubercle bacilli were found. April 26, after 2,000 c.c. had been withdrawn, there were still signs of fluid. May 3 the chest was again filled with fluid, 3,500 c.c. of which were withdrawn. May 15 the level of the fluid was from the middle of the scapula behind to the third rib in front. May 17 1,400 c.c. were withdrawn, after which the level of fluid was at the eighth rib in the midscapular line. May 25 at 8:15 a. m. he had a chill, the cause of which was

not apparent. On the same day, from 10:30 a. m. to 2:30 p. m., he was observed in the calorimeter, temperature falling from 40.10 to 39.36 C., metabolism 29 per cent. above the average normal.

He was in the calorimeter May 28 while the temperature was normal. In the course of this observation, however, he was seized with abdominal pain. During the rest of the day he had a diarrhea, and passed fourteen stools which contained much blood and mucus. This continued until May 31. Careful examination of the centrifugalized stools revealed no tubercle bacilli. June 2 he was discharged from the hospital. His temperature was normal. The signs of fluid did not change after May 17.

CASE 4.—George P. *Acute miliary tuberculosis; tuberculoma of left eye.*

*History.*—A laborer, 18 years of age, born in Greece, was admitted April 23, 1917, and discharged June 12, 1917. He came to this country from Greece in January, 1917. He had never had any serious illness.

The latter part of March, 1917, he lost his appetite, felt feverish, and had several night sweats. A few days later he found that he could not see with his left eye. He had coughed continually since the onset of the trouble, and for a month had sharp, stabbing pain in the left side of the chest. Since he came to this country he had lost twenty-five pounds in weight, dropping from 154 to 129 pounds.

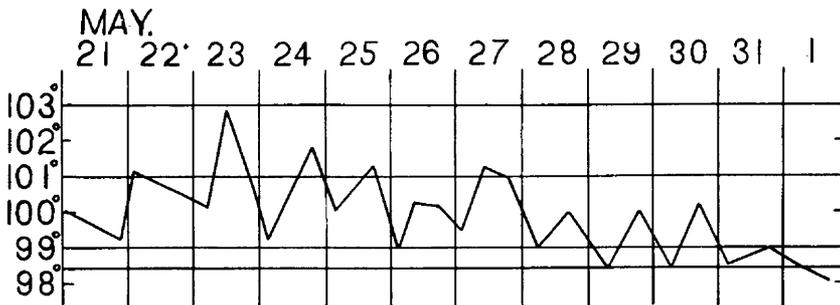


Fig. 2.—Temperature chart of Robert W.

*Physical Examination.*—Patient was a well developed, moderately emaciated boy, height 172 cm., weight 58.5 kg. His face showed a high color and his vasomotor system was very unstable. The eyes were normal externally. The retina of the right eye was normal. In the left retina there was a tumor, white in color, above and to the temporal side of the optic disk, about two disks in width, three disks in length. It was elevated six diopters above the surrounding retina. There was a small hemorrhage into the retina on the temporal side of the tumor. Lungs: There was a dulness to percussion and prolonged, high pitched, bronchial breathing at the right apex posteriorly. Anteriorly there were many constant, fine râles. At the left base there were many coarse, leathery friction râles. The cervical, axillary and inguinal lymph nodes were palpable.

On later examination, April 22, the tumor in the left retina was found to be elevated eleven diopters and to have spread to involve the optic disk.

*Laboratory Examination.*—Urine: negative. Blood: Leukocytes, 7,000; polymorphonuclears, 70 per cent.; erythrocytes, 3,600,000. Tuberculosis fixation test was positive. Questionable tubercle bacilli were found once in the sputum. The roentgenogram showed a diffuse miliary tuberculosis with a cavity at the right apex.

May 24, he was observed in the calorimeter; temperature varied from 37.5 to 37.8 C.; basal metabolism, 11 per cent. above the average normal.

The cough and pain in the chest continued and were very troublesome. With the exception of the rapid growth of the tuberculoma in the left eye, his condition changed very little after admission to the hospital. He was sent to a tuberculosis sanitarium June 12.

TABLE 4.—DIET CHART AND NITROGEN BALANCE IN CASE 4

Name and Date	Total Food, Cals.	Carbo- hydrate, Gm.	Fat, Gm.	Food N, Gm.	Excreta N,* Gm.	N Balance, Gm.	Body Weight, Kg.
George P.							
5/24/17	1,800	208	72	10.6	10.0	+0.6	58.6
5/25/17	2,500	241	120	15.1	11.8	+3.3	58.6
5/26/17	2,530	236	125	15.6	13.4	+2.2	58.1
5/27/17	2,530	242	122	15.8	17.4	-1.6	58.5
5/28/17	2,580	283	110	15.0	15.1	-0.1	
5/29/17	2,930	420	122	2.9	10.2	-7.3	58.4
5/30/17	3,140	458	127	3.0	6.4	-3.4	
5/31/17	3,040	449	119	3.5	5.5	-2.0	59.2
6/ 1/17	2,960	395	136	3.1	5.1	-2.0	
6/ 2/17	2,380	283	123	2.9	4.2	-1.3	58.1
6/ 3/17	2,600	336	123	3.1	5.0	-1.9	
6/ 4/17	2,700	346	128	3.4	4.8	-1.4	58.1

\* Fecal nitrogen estimated.

CASE 5.—Spencer C. *Pulmonary tuberculosis, both lungs, with cavitation.*

*History.*—A negro, aged 46 years, was admitted Dec. 8, 1919, complaining of shortness of breath, weakness and cough. One brother had died of tuberculosis. The patient's early life had been spent under poor conditions, but his health had been good up to 1916 when he was discharged from the army. Since then his occupation had been that of janitor. During the last two years he had continually "felt below par," progressively losing weight and strength. During this time he had a chronic cough which was worse at night and frequently kept him from sleeping. The cough became productive of a tenacious, greenish sputum in which he had never noted the presence of blood. During the year before admission, the wasting progressed rapidly, so that he was sixty-five pounds below his best weight (163 pounds). He had occasional night sweats. In the past few months he had noted increasing shortness of breath, at first only on exertion, but later while lying in bed. His cough had become so severe as to induce vomiting. One month before admission he had dull pains all over the chest, but these had disappeared. His appetite was whimsical. Bowels were constipated.

*Physical Examination.*—Patient was a fairly well developed, emaciated negro, lying flat in bed but showing considerable dyspnea, height 169 cm., weight 44.4 kg. Lips showed some cyanosis. Facies showed exhaustion and lethargy. Eyes were very prominent, with considerable bulging of the periocular tissues. The few remaining teeth were carious. The tonsils were markedly enlarged and cryptic. On both sides of the neck there were numerous, enlarged lymph nodes about the size of a bean. Thorax: showed retractions above and below both clavicles. The expansion was poor, but more limited on the right side. Lungs: showed impaired resonance over the entire chest, more marked on the right side. On auscultation bronchial breathing was heard over both upper lobes, with many medium and coarse râles heard over the entire chest. Near the inner end of the spine of the right scapula posttussive suction was heard. Heart: not enlarged. The first sound was of poor quality, the pulmonary second sound was accentuated. Rhythm was regular, but the rate was very rapid. Arteries: thickened but not tortuous.

Blood Pressure: Systolic, 115 mm.; diastolic, 65 mm. Abdominal findings: negative. Lymph nodes: enlarged in neck, axillae, inguinal and epitrochlear regions. Genitalia: normal. Fingers and toes: showed marked clubbing. There was slight edema of the ankles. Reflexes: Achilles and patellar reflexes not obtained.

*Laboratory Examination.*—The sputum showed numerous tubercle bacilli. Urine: normal, except for low specific gravity. Roentgenogram of chest showed diffuse peribronchial infiltration of the entire right lung, with numerous small cavity formations at the right apex. Numerous foci of peribronchial infiltration scattered irregularly throughout the central portion of the left lung. The temperature course is shown in Figure 3.

The patient was observed in the calorimeter December 10, the basal metabolism being 12 per cent. above the average normal for his surface area during a period of normal temperature.

Patient left hospital two days later and subsequent history is unknown.

CASE 6.—Edith B. *Pulmonary tuberculosis, both lungs, with cavitation.*

*History.*—Colored female, aged 20 years, admitted Dec. 12, 1919, complaining of pain in the left side of chest, cough and weakness. One aunt died of

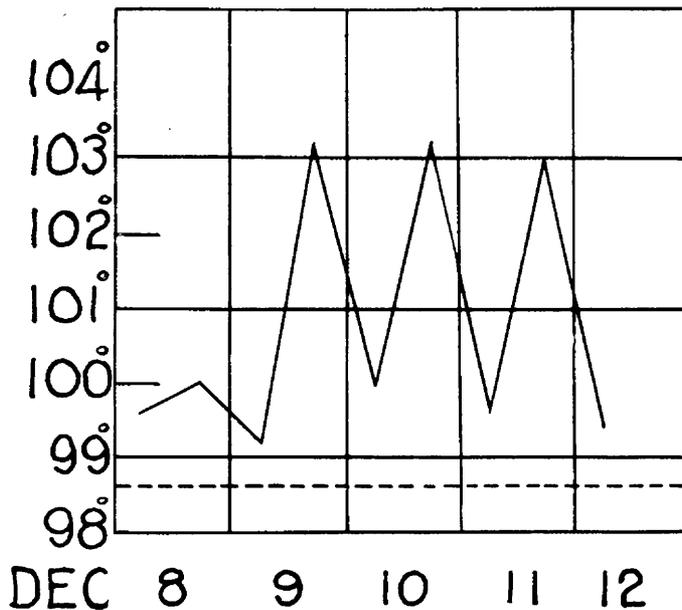


Fig. 3.—Temperature chart of Spencer C.

tuberculosis. Her mother had a disease of the spine with partial paralysis of one leg. The patient had been married eighteen months but had had no pregnancies. In childhood she had whooping cough and measles. In 1916 she had pneumonia. Otherwise her health had been good up to the onset of the present illness. Her normal weight was 135 pounds.

Early in September, 1919, patient became very weak and dizzy about 4 p. m., and at this time she felt chilly. Soon after this she developed a troublesome cough which was much worse at night. She expectorated a moderate amount of mucoid sputum in which no blood was noticed. At this time she was engaged in nursing an aunt who died one month later of consumption. A little later she began to have a great deal of pain in the left side of the chest on coughing and on deep breathing. These symptoms continued to grow worse until she was confined to bed most of the day. Her appetite was very poor. She lost weight, from 135 to 109 pounds. She had "hot fevers" at night, followed by sweats. She was admitted to the service of Dr. James Alexander Miller, through whose kindness she was transferred for study.

*Physical Examination.*—The patient was a young negro woman, 178 cm. tall, weighing 44.6 kg., alert and intelligent, lying on her side in bed, breathing rapidly and coughing occasionally. Mucous membranes were pale and not cyanotic. Thorax: well formed, but with moderate retractions above and below clavicles, most marked on the left side, involving the second and third interspaces. The expansion of the right side of the chest was fairly free, but there was marked limitation of motion of the left side. Lungs: Percussion note was resonant at both bases, but there was no excursion at the left, while at the right base there was an excursion of 5 cm. Both apices were dull both front and back, more marked on the left. There was diminution of the voice and breath sounds at the left base behind, and over the dull areas the breathing was bronchovesicular or bronchial in character, with many fine râles. Heart: Apex impulse could not be located. The cardiac dullness extended 12 cm. to the left in the fifth intercostal space, but the right border could not be sharply located. Rate rapid; rhythm regular. No murmurs heard. Pulse: rapid and of low tension. Arteries: normal. Abdomen: negative. Genitalia: not examined. Extremities: normal. Reflexes: normal. Epitrochlear lymph nodes: enlarged.

*Laboratory Examination.*—Sputum contained many tubercle bacilli. Urine: normal. Roentgenogram of chest showed infiltration, fibrosis and cavitation of the middle portion of the right lung and the entire left lung with the exception of a small portion of the left base. Cavity formation was located in the upper

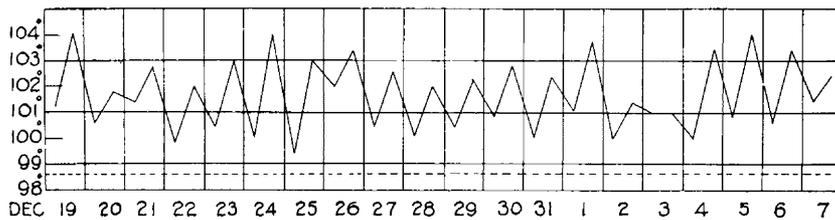


Fig. 4.—Temperature chart of Edith B.

portion of the middle lobe, but there were also numerous small cavities in the left lung. There were many pleuropericardial adhesions, with marked distortion of the cardiac outline. Compensatory emphysema in the right lung and fibrosis in the left lung.

Observations were made in the calorimeter December 7 and 19 and January 6. The first observation made at normal temperature showed no elevation of the basal metabolism. Subsequent observations during high fever, with coughing, raised the metabolism from 18 to 20 per cent. above the average normal and still further increases were due to restlessness during the third observation. The mechanism of temperature regulation in this case is shown graphically in Figure 14.

**CASE 7.—Harry G. Pulmonary tuberculosis, extensive bilateral infiltration.**

*History.*—A fountain-pen maker, 18 years of age, was admitted Jan. 2, 1920, complaining of cough, weakness and night sweats. He had measles in childhood, but was well and active, though rather weak as a boy. At the age of 16 he went to work in a fountain-pen factory, where the work was confining and the atmosphere full of dust. His appetite was poor, bowels constipated, but he had no respiratory symptoms until November, 1919.

At that time he caught cold and began to have a racking cough with a moderate amount of viscid sputum. The cough reached its maximum intensity one month before admission, after which it was less troublesome. It was most severe at night, when it sometimes produced vomiting. He had night sweats

before entering the hospital, but none during his stay. Two weeks before admission he coughed up about one teaspoonful of bright blood. He had become very constipated. He had no urinary symptoms. His greatest weight was 123 pounds; admission weight was 109 pounds. He felt loss of strength very much.

*Physical Examination.*—Patient was a pale, poorly developed, poorly nourished boy of 18 years, height 163 cm., weight 42.7 kg. There were small but distinctly palpable nodes on both sides of the neck. Thorax was carinate. There was retraction above and below both clavicles, more marked on the left side. The entire left chest showed retraction and marked limitation of expansion. Lungs: Both upper lobes were dull on percussion, the left to the second intercostal space in front and to the angle of the scapula behind; the right was dull only above the clavicle in front and to the spine of the scapula behind. Over these dull areas the breath sounds were bronchial in quality, with many medium sized and fine râles. No excursion of the left base was found, while the maximum excursion of the right base was 2 cm. At the left base there was slight dullness, bronchovesicular breath sounds and many moist râles, front and back. Heart not enlarged nor displaced. There were no murmurs. The rate was quite rapid, but the rhythm was regular. Pulse was rapid and soft. Blood pressure: Systolic 120 mm.; diastolic 80 mm.

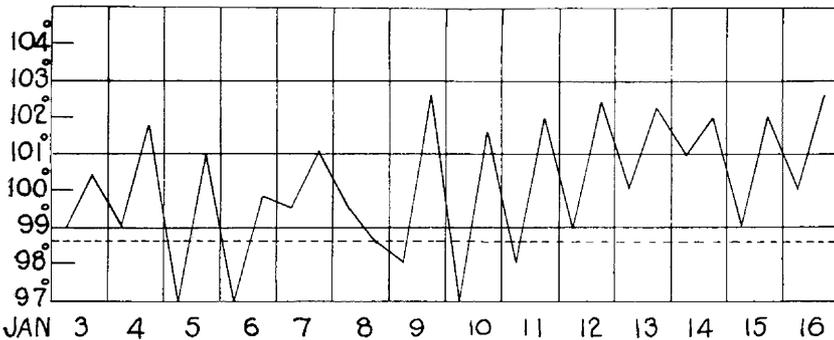


Fig. 5.—Temperature chart of Harry G.

Further examination negative. Urine was normal. Sputum showed numerous tubercle bacilli. Fluoroscopy showed a very diffuse parenchymatous infiltration of both upper lobes, particularly of the left side, with a small antrum beneath the left pole (Dr. J. A. Miller).

One observation was made in the calorimeter January 13. The temperature fell from 39.20 to 38.94 C., pulse 120. The metabolism was 21 per cent. above the average normal, but the conditions were not basal on account of restlessness.

CASE 8.—Joseph D. *Pulmonary tuberculosis, infiltration of both upper lobes and left base.*

*History.*—A machinist, aged 33 years, was admitted Dec. 3, 1919, complaining of pain in the left side of the chest and cough. His father, mother and one brother died of pneumonia and one uncle died of "lung trouble." In childhood he had dysentery, mumps, whooping cough, "chills and fever." In 1915 he was treated for "lung trouble" in a hospital. He had a bad cough at that time. While under treatment he worked for one year. In April, 1919, he was in Bellevue Hospital on account of pleurisy and cough. Following this he had a chronic cough and occasionally night sweats. He was very short of breath on exertion and had palpitation but no edema. His appetite was good, bowels regular. He urinated three to four times during the night. He had gonorrhoea fifteen years ago. His best weight was 135 pounds.

Nov. 25, 1919, while digging a trench, he felt a sudden, sharp pain in the left side of the chest and across the back. He stopped work but did not go to bed. Pain and cough increased daily so that he entered the hospital December 3. At that time the physical findings, confirmed by the roentgen ray, led to a diagnosis of bilateral apical tuberculosis. The temperature range was from 97.4 to 100 F. Leukocytes, 14,000, with polymorphonuclears 65 per cent.; lymphocytes, 23 per cent.; large mononuclears, 10 per cent.; eosinophils, 1 per cent. Hemoglobin, 73 per cent. Urine was normal.

He was allowed to leave the hospital on pass, but did not return. He was readmitted Jan. 14, 1920, with a temperature of 102 F., having had severe chills.

*Physical Examination.*—A well developed, fairly well nourished man, height 177 cm., weight 59 kg., face flushed, eyes bright, respirations rapid but not labored. Chest: Retraction of both supraclavicular and infraclavicular fossae. Expansion limited most markedly on the right side. Lungs: Both apices were dull from the second intercostal space in front to the spine of the scapula behind and there was dullness at the left base behind. Breath sounds at both apices were tubular, with crepitant and moist râles. In the left chest in front there was a coarse friction rub between the fourth and seventh intercostal spaces. At the left base behind many coarse râles were heard. Heart was not enlarged; rate 80; rhythm regular; no murmurs. Pulse was full and soft, artery not thickened. Further examination was negative.

The patient improved rapidly though he had a moderate, irregular fever for about nine days. January 15 he complained of huskiness of the voice and pain in the larynx on swallowing. Examination showed a thickening of the arytenoids and of the anterior commissure. The cords were thickened and lacked the normal luster but approximated throughout.

*Laboratory Examination.*—Sputum showed no tubercle bacilli. The roentgen ray showed a patch of peribronchial infiltration in the peripheral portion of the right apex. There was fibrosis of the left apex, emphysema of both lungs, more on the right. There was production of fibrous tissue in the lower lobe of the left lung, but no peribronchial infiltration. Adhesions at the left base.

*Diagnosis.*—Early second stage tuberculosis, right apex; fibroid tuberculosis, left apex; interstitial inflammation of the left lower lobe; pleural thickening of the right upper lobe; deviation of the heart to the right, axis almost vertical.

The last day of fever was January 16. He was put in the calorimeter on the seventeenth, at which time his basal metabolism was found to be 90 per cent. of the average normal in one hour in which he was very quiet.

CASE 9.—Michael C. *Pulmonary tuberculosis with cavitation, laryngeal tuberculosis.*

*History.*—A furrier, aged 33 years, complained of hoarseness and shortness of breath. He was in perfect health up to January, 1919, when he engaged in a drinking bout with some friends. He sang very loudly and on the following day he was quite hoarse. Soon a cough developed with some expectoration. No medicine gave any relief, his cough and hoarseness grew worse, he began to have night sweats and to lose weight and strength. He remained at work, however, until August, 1919. At this time he became very short of breath and felt great oppression of the chest. His cough was more and more productive, but hemoptysis occurred on only one occasion and then in very small amount. He spent November and December in Colorado, where he improved somewhat. Two weeks before admission he returned to New York. He caught cold and had a recurrence of his worst symptoms. He developed complete aphonia. His best weight was 130 pounds; admission weight was 110 pounds.

*Physical Examination.*—Fairly well developed but emaciated man, height 179 cm., weight 50 kg., lying flat in bed, breathing rapidly, extremely weak and ill. Laryngeal examination was difficult, but showed marked congestion of epiglottis, arytenoids and vocal cords and laryngeal walls. There were a few enlarged lymph nodes in the neck on both sides. Thorax was well formed,

but there were retractions above and below both clavicles. Expansion was limited on both sides, but more so on the right. Lungs: Both apices dull to percussion, right front dull to the fifth rib and behind to the angle of the scapula. The left apex was dull from the second rib to the middle of the scapula behind. Over the dull areas the breathing was in general bronchovesicular, with many fine and medium moist râles. Over the third intercostal space in the mid-clavicular line the breathing was amphoric in character. Further examination was negative.

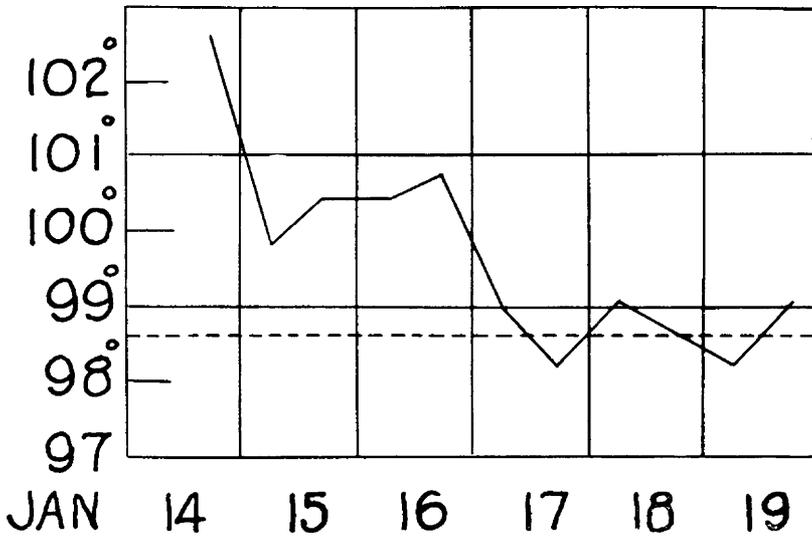


Fig. 6.—Temperature chart of Joseph D.

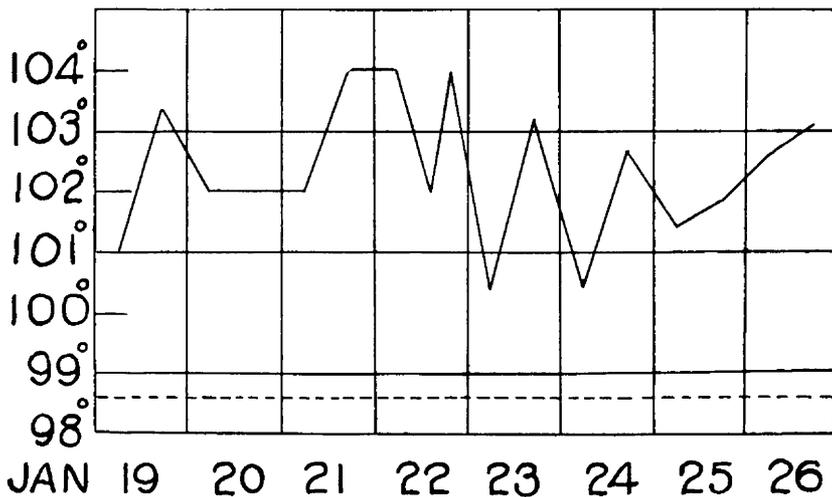


Fig. 7.—Temperature chart of Michael C.

Pulse ranged from 86 to 128 and respirations from 22 to 28. Sputum was full of tubercle bacilli. Urine was normal.

The patient was observed in the calorimeter Jan. 22, 1920. With the rectal temperature falling from 39.8 to 39.2 C. and pulse 120, the metabolism was 31 per cent. the first hour and 24 per cent. the second hour above the average normal; the conditions were not basal as the patient coughed incessantly. The subsequent history is unknown.

CASE 10.—Anna H. *Bronchopneumonia; phthisis.*

*History.*—Sewing machine girl, aged 17 years, was admitted Jan. 25, 1920, complaining of pain in the chest and cough. She had worked two years in the factory, during which time her weight had dropped from 122 pounds to 113 pounds. She was well up to the onset of the present illness, which began Nov. 25, 1919, with a bad cold. The cold did not improve, but she remained at work until Jan. 11, 1920, when her illness became acute, with severe cough and pains in the chest. After remaining in bed for two days she attempted to return to work. She became worse rapidly, coughed constantly and had night sweats. Her weight dropped from 113 to 90 pounds.

*Physical Examination.*—On admission, January 25, the pharynx was congested, tongue coated, heart normal. Lungs showed no dulness, but numerous, squeaking râles were heard on both sides in back. Temperature, 103 F.; pulse, 100.

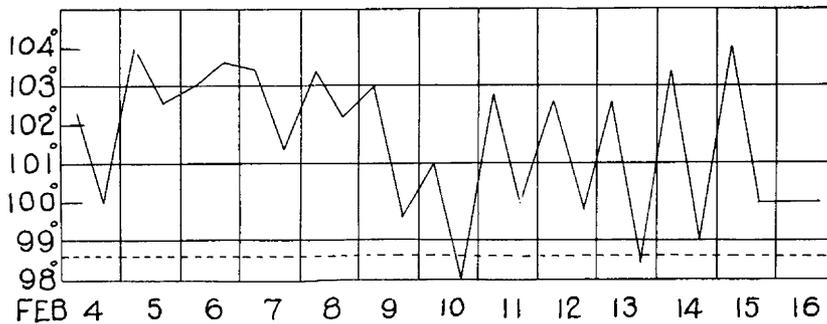


Fig. 8.—Temperature chart of Anna H.

*Tentative Diagnosis.*—Acute bronchitis.

January 28 numerous tubercle bacilli were found in the sputum. On the following day a note was made: "Thorax symmetrical and well developed. Respiratory excursion is slightly restricted. There are no retractions or bony prominences. There is a widespread process extending through all lobes of both lungs, but most advanced at the bases, characterized by bronchovesicular breathing, and many fine, medium and large moist râles. At both bases posteriorly there is dulness, most marked at the left. At the apex of the heart there is a localized systolic murmur. Over the base of the heart there is a longer, rough murmur heard in systole."

*Laboratory Examination.*—Urine examinations were all normal. Blood: Feb. 4: Leukocytes, 10,000; polymorphonuclears, 70 per cent.; transitionals, 2 per cent.; lymphocytes, 25 per cent.; eosinophils, 3 per cent. Hemoglobin, 60 per cent.

She was studied in the calorimeter February 5. The temperature rose from 39.38 to 39.64 C.; pulse 132. The metabolism was 21 per cent. above the average normal, but was not basal, as the patient was coughing throughout the observation.

February 7 the physical examination was as follows: "A normally developed girl of 17, past puberty, very emaciated and pale, height 165 cm., weight 41 kg. There is a bright flush over the left malar region; eyes are bright; breathing very rapid but not labored. Thorax shows limitation of expansion of the left

side. There are retractions above the clavicles, and on the left side in the first and second interspaces and at the left base and axilla. Lungs are dull at both apices, and the left lung is dull throughout. The right base is resonant below the angle of the scapula. Over the dull area there is an increase in vocal and tactile fremitus, tubular breathing at the apices and bronchovesicular breathing at the left base. Over the whole chest fine, medium and coarse moist râles are heard. Heart is normal. Pulse rapid, 120, regular, and of very low tension. Abdomen is somewhat distended, but otherwise normal." Further examination was negative.

February 20 the signs of consolidation were intensified. Numerous crackling râles and in many places creaking friction rubs were heard.

The patient died two days later. A necropsy was not permitted.

CASE 11.—John H. *Pulmonary tuberculosis.*

*History.*—A chauffeur, aged 25 years, was admitted complaining of pain in the chest, headache and chills. He was well and strong up to the time of his enlistment in the British Army, Tank Service, in 1916. He served nine months at the front and remained well until he was gassed with chlorin. He was sick for three or four months with cough and afternoon fever, but was finally returned to duty. He remained well and was discharged physically fit. He was able to do all sorts of work up to the end of November, 1919, when he

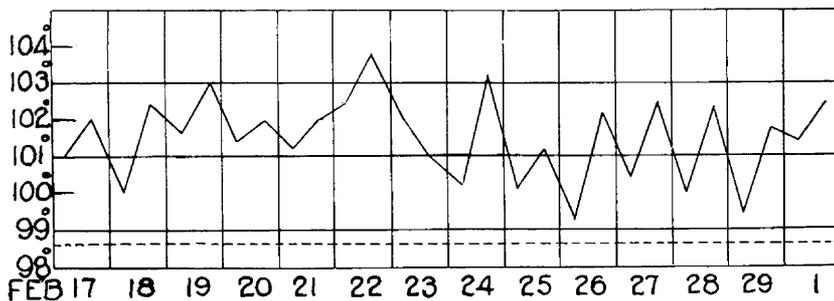


Fig. 9.—Temperature chart of John H.

was taken sick with pneumonia and treated in the Metropolitan Hospital for four weeks. He had been out of the hospital only three weeks when he was again taken sick and admitted to Bellevue Jan. 24, 1920. Three days before admission patient had a severe cough and soreness in the chest. He went to bed and stayed there until the following day. A doctor gave him some whisky. He took it and the next day was admitted in an intoxicated condition. Later he said his best weight was 142 pounds and that he had maintained this up to November. Present weight, 100 pounds.

*Physical Examination.*—Height, 175 cm., weight 45 kg. Well developed, pale, emaciated young man. Lips somewhat cyanotic and parched. Chest: Well formed with deep supraclavicular fossae. Expansion was fairly good, but more limited on the right side. Lungs: Left apex was dull from the second rib in front to midscapula behind, with bronchovesicular breathing and many fine râles. Left base was resonant except in midaxilla, where there was slight dullness and a creaking rub was heard. The right lung was dull throughout, most marked at the apex, where the breath sounds were tubular and accompanied by fine râles. At the right base the breathing was bronchovesicular, with many medium and fine râles. Heart was normal in size and position; no murmurs. Rhythm was regular. Pulse was soft and rapid. Blood pressure: Systolic 100; diastolic 60. Further examination was negative.

*Laboratory Examination.*—Sputum contained many tubercle bacilli. Urine examinations were normal throughout. Blood: Leukocyte counts, January 26, 10,500; February 6, 13,600; polymorphonuclears, 64 per cent.; transitionals, 18 per cent.; lymphocytes, 4 per cent.; large mononuclears, 13 per cent.; eosinophils, 1 per cent. Roentgenogram of chest, February 9, showed diminished illumination over the upper halves of both pulmonic fields. There was considerable increase in the size, number and density of the pulmonic markings throughout this area. These markings were confluent. There was considerable increase in density of both hilus shadows. The costophrenic sinuses were clear. The diaphragmatic outlines were normal. The heart shadow was slightly displaced to the left. Infiltration of upper halves of both lungs.

*Diagnosis.*—Tuberculosis.

He was studied in the calorimeter February 10. With a normal temperature his basal metabolism was 15 per cent. above the average normal. February 12, the specific dynamic effect of a meat meal was studied (Fig. 15). This meal

TABLE 5.—DIET CHART AND NITROGEN BALANCE IN CASE 11

Name and Date	Food			Food N, Gm.	Urine N, Gm.	Feces N, Gm.	Excreta N, Gm.	N Balance, Gm.	Body Weight, Kg.
	Total Calories	Carbohydrate, Gm.	Fat, Gm.						
John H.									
4/17/20	1,650	147	83	10.7	9.0	1.1	10.1	+0.6	44.6
4/18/20	1,977	185	92	14.2	....	1.4	....	....	....
4/19/20	1,830	194	78	13.8	9.0	1.4	11.4	+2.4	44.8
4/20/20	....	....	....	....	6.8	....	....	....	44.7
4/21/20	....	....	....	....	10.8	....	....	....	....
4/23/20	1,890	156	95	14.5	....	1.5	....	....	43.8
4/27/20	1,848	152	93	14.1	14.5	1.4	15.9	-1.8	....
4/28/20	1,848	152	93	14.1	17.6	1.4	19.0	-4.9	44.0
4/29/20	1,848	152	93	14.1	13.7	1.4	15.1	-1.0	44.2
4/30/20	1,964	173	95	14.4	12.3	1.4	13.7	-0.7	43.9
5/ 1/20	1,964	173	95	14.4	11.6	1.4	13.0	+1.4	43.8
5/ 2/20	2,055	180	100	15.0	11.6	1.5	13.1	+1.9	....
5/ 3/20	2,123	185	104	15.7	13.9	1.6	15.5	+0.2	44.3
5/ 4/20	1,734	169	92	7.1	7.6	2.1*	9.8	-2.6	....
5/ 5/20	1,739	169	93	7.1	8.8	2.1*	10.9	-3.8	44.7
5/ 6/20	1,739	169	93	7.1	5.7	2.1*	7.8	-0.7	44.7
5/ 7/20	1,737	169	92	7.1	6.4	2.1*	8.5	-1.4	....
5/ 8/20	1,737	169	92	7.1	3.8	2.1*	6.9	+0.2	44.7
5/ 9/20	1,737	169	92	7.1	5.6	2.1*	7.7	-0.6	....
5/10/20	1,737	169	92	7.1	5.4	2.1*	7.5	-0.4	44.9
5/11/20	2,975	188	121	3.2	5.4	1.0	6.4	-3.2	44.8
5/12/20	2,965	183	121	3.3	4.6	1.0	5.6	-2.3	44.5
5/13/20	1,914	181	118	3.0	3.7	1.0	4.7	-1.7	44.0
5/14/20	1,914	181	118	3.0	3.1	1.0	4.1	-1.1	44.3
5/15/20	1,915	181	118	3.0	....	....	....	....	44.2

\* Analysis made. Remaining fecal nitrogen estimated.

consisted of 350 gm. of lean beef and 10 gm. butter (protein 70 gm., fat 28 gm.). From a basal heat production of 69.3 calories per hour, his metabolism rose in successive hours after the meal to 77.0, 82.4 and 86.8 calories per hour, respectively. This corresponds closely with the results obtained with normal subjects.

Considerable improvement in the patient's condition occurred, his appetite was better. He still had considerable pain in the left chest.

March 1 his metabolism was 17 per cent. above the average normal, temperature between 38.68 and 38.71 C., very quiet.

During the month of March marked improvement continued. The temperature range gradually became smaller and lower. His cough almost ceased. His appetite was good and during this time he was given the ordinary soft, special diet of the hospital, not measured. The total caloric value of this diet is not high. He remained at the same weight, 100 pounds, with very slight variations.

His basal metabolism was again determined April 14; rectal temperature from 37.8 to 37.4 C. His metabolism was 5 per cent. above the average normal. From this his daily basal heat production was estimated at 1,512 calories. This was done as a preliminary to complete dietary control in the metabolism ward. The temperature and graphic record of this study are given in Figure 18. The observed data are given in Table 5. The stools for the different periods were marked off with carmine and saved for analysis, the total nitrogen for the period was determined, and the daily average added to the urine nitrogen figure. The study was made to determine the minimum level at which nitrogen balance could be attained and the minimum to which the protein metabolism could be reduced as a means of estimating the toxic destruction of protein.

CASE 12.—William H. *Pulmonary tuberculosis, tuberculosis of hip joint.*

*History.*—A laborer, aged 31 years, was admitted in February, 1920, complaining of pain in the chest, cough, loss of weight and weakness. At the age of 2 he had whooping cough and later measles. When 3 years old he had hip disease, for which he was treated at the Postgraduate Hospital. He wore a brace until the age of 13. During this period his health was good. His growth was normal. He had always done hard manual labor outdoors until shortly before the present illness. Late in the fall of 1919 he worked in a factory

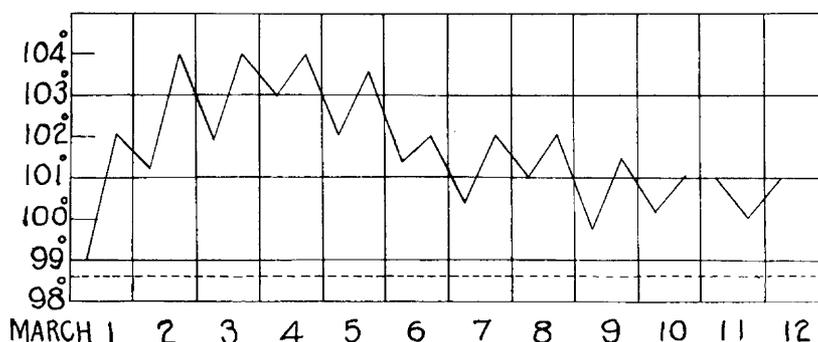


Fig. 10.—Temperature chart of Wm. H.

where he was confined in a dusty room. He felt wretched during his stay in this position and gave it up. He then worked on the city streets shoveling snow. February 7 he became very wet and was exposed all day. He felt a sudden, sharp pain in the left chest and back. In the Bellevue Dispensary tubercle bacilli were found in the sputum and, therefore, he was admitted to the hospital. During the week prior to admission he had night sweats, severe cough, with abundant sputum in which no blood was noted. His best weight was 135 pounds, but just before the onset of illness it was 130 pounds. Weight while in the hospital was 110 pounds.

*Physical Examination.*—Height 165 cm., weight 49.7 kg. Patient was a fairly well nourished young man of medium size who looked acutely ill. Thorax: Slight asymmetry due to a scoliosis. Respiratory movements fairly free and symmetrical. There were no retractions. Lungs: Apices were dull on both sides above and just below the clavicles. Behind, the dullness, which was most marked at the extreme apex, shaded into normal resonance about the level of the sixth dorsal spine. Over the apices the breath sounds were bronchovesicular, with many fine râles. Between the scapula many coarse moist râles and sibilants were heard. Elsewhere the breath sounds were normal. Heart: Of normal size and position. No adventitious sounds were heard. The rate was rapid, rhythm regular. Pulse rapid and soft. Blood pressure: Systolic, 105 mm.; diastolic, 85 mm. There was ankylosis of the left hip, with

complete limitation of motion. The muscles of the left thigh and calf were atrophied. The left leg was two inches shorter than the right. There were no other abnormalities.

*Laboratory Examination.*—Sputum contained many tubercle bacilli. Urine examinations were normal throughout. Blood: Leukocyte count, March 3, 10,400; hemoglobin, 90 per cent. March 8: Wassermann reaction negative. Roentgen-ray report showed pulmonic fields of equal size. There was diminution of illumination over the upper half of the left pulmonic field. The apices were clear. There was considerable increase in the hilum shadows, with calcific foci on the right. The pulmonic markings were increased in size, number and density over the upper half of the left pulmonic field, with agglutination. Over the right pulmonic field there was increase in the size, number and density of the pulmonic markings, with confluence. There was an irregularity in the outline of the right diaphragm. The costophrenic sinuses were clear. The heart was large, generally rounded in outline and median in position.

March 24: Vital capacity equaled 2,795 c.c. The normal for the present surface area, according to the calculations of West, is  $1.53 \times 2,500 = 3,825$  c.c., but the normal surface area for health is 1.66 square meters, hence the normal vital capacity would be 4,150 c.c.

March 2 the metabolism was 18 per cent. above the average normal when his temperature was 38.58 C. and the patient was very quiet. At the same temperature in the next hour the heat production was raised 5 per cent. more by coughing.

March 10 the basal metabolism was 9 per cent. above the average normal when the rectal temperature was 38.0 C.

The specific dynamic action of a protein meal was studied. The meal consisted of 350 gm. meat with 10 gm. butter (protein 70 gm., fat 28 gm.). From a basal heat production of 65.6 calories per hour, the metabolism rose after the meal to 68.7, 73.9 and 86.1 calories per hour in successive hours. This corresponds closely with the behavior of the normals studied (Fig. 15).

CASE 13.—John S. *Pulmonary tuberculosis, mitral stenosis, and regurgitation, compensated.*

*History.*—A machinist, aged 28 years, was admitted complaining of a feeling of fatigue and of swelling of the feet and ankles. He had no illness in childhood except occasional sore throat. At the age of 20 he had mumps. In 1913 he had typhoid fever. In 1919 he had two attacks of acute rheumatic fever. He had gonorrhoea three times. He was in quite good health until the spring of 1919, when he had a severe cold, which persisted. He had a dry, hacking cough, which grew much worse in the course of several weeks. He lost appetite and began to have fever in the afternoon, with great weakness and prostration. He remained at work even when his temperature was high. Sputum examination by the board of health showed tubercle bacilli. At this time his afternoon temperature was 103 F. His weight dropped from 160 to 154 pounds. He was sent to a hospital for tuberculosis and later transferred to Otisville. He improved, became afebrile, and regained weight up to 160 pounds. While there he developed acute rheumatic fever after lying on the wet grass when overheated from work. He soon recovered, but had another attack in August, 1919. Following the second attack he had edema of the ankles while at work. For the past year he had to urinate three or four times during each night. Maximum weight in 1913 was 168 pounds; weight before illness in 1919 was 160 pounds; weight while in hospital, 148 pounds.

Feb. 5, 1920, his feet began to swell and he felt very tired. This continued, causing him to stop work February 10. He was admitted to Bellevue February 12, with a fever of 104 F., falling to normal in the course of forty-eight hours, and then fluctuating between 99 and 100 F. He had a mild cardiac decompensation from which he rapidly recovered, though he continued to have fever from a reactivation of his tuberculosis.

*Physical Examination.*—Patient was a well developed man, 191 cm. in height, weighing 62.3 kg. Thorax well formed, supraclavicular fossae deep, but

with greater retraction on the left. There was limitation of expansion of the left chest. Lungs were dull on percussion of both upper lobes, the left upper from the fourth rib in front to the angle of the scapula behind, the right from the third rib in front to the midscapula. Expiration was prolonged and high pitched, with many medium and fine râles. Heart: Apex impulse in the fifth intercostal space was 12 cm. to the left of midline. Dulness extended to the left 13 cm. in the fifth space and to the right 6 cm. in the fourth intercostal space. There was a suggestion of a thrill over the precordium. There was a presystolic murmur of rough, crescendo quality at the apex, and also a systolic murmur heard at the apex, in the axilla and to the right of the sternum in the fourth space. The second pulmonic sound was accentuated. The rate was

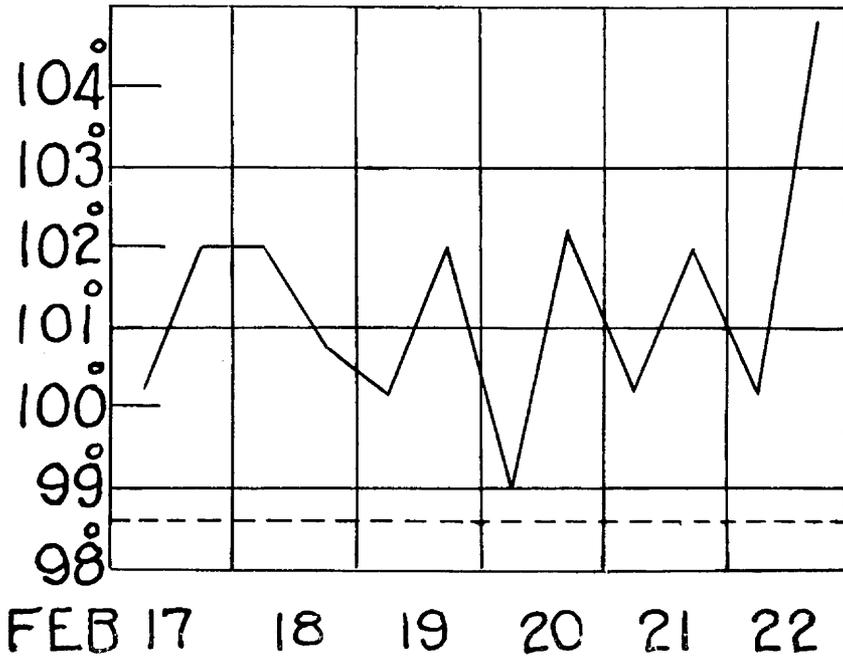


Fig. 11.—Temperature chart of John S.

120, rhythm regular. Pulse was dicrotic. Blood pressure: Systolic, 105 mm.; diastolic, 60 mm. Liver was not felt. Further examination was negative.

*Laboratory Examination.*—Sputum contained many tubercle bacilli. Blood: Leukocyte count on admission was 14,200, of which 84 per cent. were polymorphonuclears, 4.5 per cent. large mononuclears, 1.5 per cent. transitionals, 9.5 per cent. lymphocytes. Red cell count was 4,152,000. Hemoglobin, 75 per cent. Urine examination was negative.

He was studied in the calorimeter February 17, at which time his basal metabolism was found to be 14 per cent. above the average normal, with temperature falling between 37.8 and 37.4 C. On a second occasion the observation was unsuccessful because he was eliminating water from the skin and lungs at the rate of about 72 gm. per hour, which surpassed the capacity for ventilation of the calorimeter.

CASE 14.—George M. *Pulmonary tuberculosis, with cavitation.*

*History.*—A machinist's helper, aged 31 years, was admitted March 15, 1920, complaining of chills, fever and night sweats and severe cough. In childhood he had whooping cough and measles at the age of 9 years. He was in perfect health until he went to India in 1917 in the transport service of the Mesopotamia campaign. While there he had "sand fly fever," for which he was treated with quinin. He also had dysentery which became chronic. Each winter following 1914 he had colds and persistent cough, nevertheless remaining in fairly good health. His appetite was habitually poor. He had a soft chancre in 1911 and later had gonorrhoea also. He has had no secondary manifestations of syphilis. His maximum weight was 137 pounds.

In the winter of 1919-1920 the patient had his usual winter cough, but it was much more severe than usual. It kept him awake at night. He became very weak and "run down." Sputum was never bloody. About February 15 he began to feel chilly in the afternoon and at night he had severe sweats.

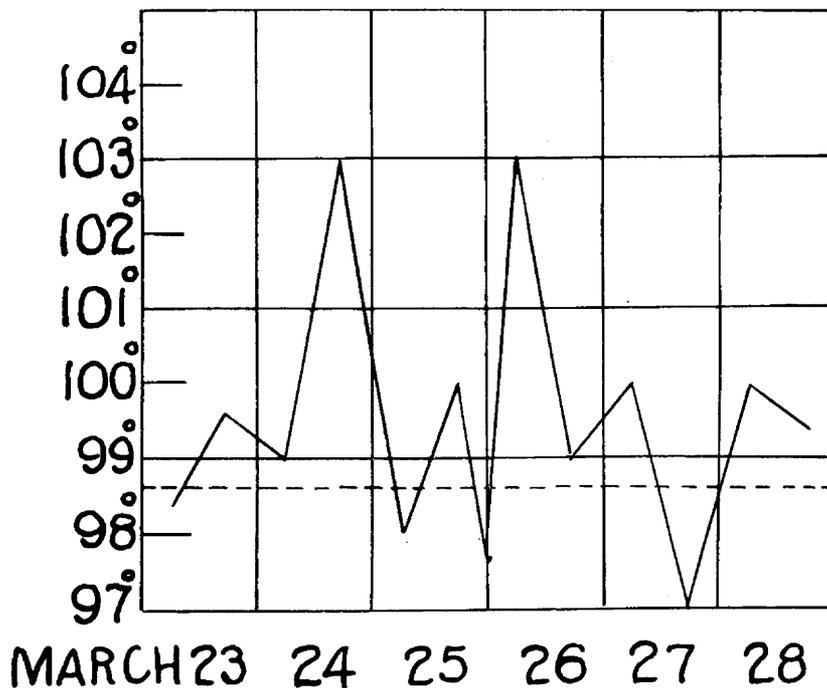


Fig. 12.—Temperature chart of George M.

His cough became worse and the expectoration blood tinged. He had had much substernal and precordial pain, aggravated by coughing. Vomiting was sometimes induced by the severity of the cough.

*Physical Examination.*—The patient was a small, thin man, 165 cm. tall, weighing 49.1 kg. Thorax of normal shape, but with marked supraclavicular retractions. Respiratory excursions were symmetrical and apparently not limited. Lungs: Both apices quite dull on percussion from the third rib in front to the angles of the scapulae behind. Over the dull areas there was increased fremitus and whispered voice transmission, bronchial breathing and many fine râles. At the right apex the breathing approached amphoric in quality, especially at the extreme upper part of the right axilla. The bases were slightly dull posteriorly and the excursion of neither base exceeded one finger's breadth.

There was bronchovesicular breathing at the right base and a few coarse râles were heard at both bases. Heart not enlarged nor displaced; rate 100; rhythm regular. Blood pressure: Systolic, 85 mm. There were a few palpable nodes in both inguinal regions. Moderate clubbing of fingers. Further findings were negative.

*Laboratory Examination.*—Sputum examination showed many tubercle bacilli. Urine normal. Blood: Leukocyte count (March 17), 11,400, of which 60 per cent. were polymorphonuclears, 29 per cent. lymphocytes, 9 per cent. large mononuclears, 1 per cent. transitionals, 1 per cent. eosinophils. March 26: Leukocytes, 11,000; polymorphonuclears, 73 per cent.; lymphocytes, 17 per cent.; large mononuclears, 10 per cent.

Vital capacity, average six trials, 2,523 c.c., which is 61 per cent. of the normal, as calculated by the method of West from the surface area.

This patient was observed in the calorimeter March 24 while the temperature was falling rapidly from 39.56 to 38.72 C., with sweating. The metabolism in the first hour was 34 per cent. above the average normal and during the second it was 27 per cent. above. March 26 another observation was made while the temperature fell from 39.23 to 38.17 C., the metabolism being 29 per cent. above the average normal. The percentage of heat lost through vaporization was from 32 to 35 per cent. of the total heat eliminated. This latter observation is graphically represented in Figure 14. The conditions were not basal in either case, due to restlessness.

CASE 15.—Joseph R. *Pulmonary tuberculosis with cavitation; chronic nephritis with hypertension.*

*History.*—A printer, aged 36 years, was admitted May 3, 1920, complaining of "kidney trouble." While his health, in general, had always been good, he had had for a long time a slight, hacking cough, not productive, believed to be due to excessive smoking. He had been a heavy beer drinker. For many years he had urinated once during the night. His maximum weight was 180 pounds. In 1918 he lost weight rapidly to 161 pounds. His weight remained at 160 until six weeks before admission, when he again began to lose. Weight while in hospital was 134 pounds. About one week before admission he noticed swelling of the ankles and legs, extending within the next few days to the trunk and face. He felt nauseated and had some attacks of vomiting. He then began to urinate five or six times a night. He had not been conscious of fever and had had no night sweats. His cough had become productive, but there had been no hemoptysis.

*Physical Examination on Admission.*—Height, 175 cm.; weight, 61.13 kg. Patient was a well developed but rather poorly nourished man; lips somewhat cyanotic. He showed slight dyspnea, but sat up in bed reading comfortably. There was a slight venous pulsation in the neck. Chest was of normal shape and size. There were moderate retractions of the upper left side, seen chiefly in the second and third intercostal spaces. Lungs: Marked diminution of resonance over the whole left chest, with hyperresonance of the right. The upper left chest anteriorly was almost flat and fremitus was increased. Over this area the breath sounds were somewhat amphoric in quality. Elsewhere on the left the expiration was prolonged and high pitched. Heart: There was a general heaving of the precordium. The apex impulse was of maximum intensity in the fifth intercostal space 12 cm. to the left of the midline. The cardiac dullness extended from the right sternal margin to 14 cm. to the left in the fifth intercostal space. Rhythm was regular. There were no murmurs. There was slight accentuation of the aortic second sound. Blood pressure: Systolic, 160 mm.; diastolic, 120 mm. Arteries not thickened. Abdomen was somewhat distended and tender in the right upper quadrant. Liver was felt three fingers' breadth below the costal margin. Hands were somewhat cyanotic and puffy, but did not pit. There was some edema of both lower extremities and under the sacrum.

*Laboratory Examination.*—The urine showed a low specific gravity (1.010), considerable albumin, no sugar, many hyalin and granular casts, many red blood cells and many clumped leukocytes. Blood: May 4, leukocytes, 10,000; hemoglobin, 70 per cent.; May 6: nonprotein nitrogen, 39.5 mg. per hundred c.c.; creatinin, 1.7 mg. per hundred c.c. May 5 the sputum contained many tubercle bacilli.

The patient improved rapidly. May 12 the dyspnea was almost gone; edema very slight. The roentgen ray showed pulmonic fields of unequal size, the right being larger than the left. There was marked diminution of the illumination throughout the entire left pulmonic field, and the middle third of the right. Costophrenic spaces were clear. There was increase in size and density of the right hilum shadow. There was increase in size, number and density of the left pulmonic and also of the middle third of the right field, markings agglutinated throughout. Large cavity at the left apex. Diaphragm shadow normal. Heart enlarged, distorted in appearance, with adhesions. Fibrosis, infiltration and cavitation of the left lung, tuberculosis.

May 24 there was no edema or dyspnea. Blood pressure: Systolic, 128 mm.; diastolic, 110 mm. Fundus of each eye normal. Comfortable.

May 25 he was studied in the calorimeter. Rectal temperature 36.7 C. His heat production was 70.7 calories per hour, or 40.5 calories per square meter per hour, being 3 per cent. above the average normal. He was then studied in the metabolism ward. The diet given is shown in Table 6 and graphically in Figure 19.

May 26 the nonprotein nitrogen content of the blood was 26 mg. per hundred c.c.

June 1, 1920, a cystoscopy was done. The cystoscope passed easily into the bladder and some clear urine was obtained. Bladder capacity normal. Bladder neck and fundus normal, but many trabeculations were seen on the posterior bladder wall. Mucosa normal. Both ureteral orifices were normal. Specimens were obtained from both sides, but no further report was made.

TABLE 6.—DIET CHART AND NITROGEN BALANCE IN CASE 15

Name and Date	Total Calories	Carbohydrate, Gm.	Fat, Gm.	Food N, Gm.	Urine N, Gm.	Excreta N,* Gm.	N Balance, Gm.	Body Wt., Kg.	Urine Vol., C.c.	Water Intake, C.c.	NaCl Intake, Gm.	Urine NaCl Gm.
Joseph R.												
5/15/20	1,678	165	83	9.1	9.5	10.5	-1.4	64.0	2,155	1,900	7.61	
5/16/20	1,886	183	92	10.8	10.6	11.6	-0.8	....	2,080	1,990	7.61	
5/17/20	1,823	189	85	10.0	10.7	11.7	-1.7	62.5	2,030	2,000	7.99	8.48
5/18/20	1,992	229	85	10.2	8.0	9.0	+1.2	61.8	2,210	2,224	7.45	9.57
5/19/20	2,261	277	94	10.0	8.2	9.2	+0.8	....	1,630	2,004	7.26	6.15
5/20/20	2,002	250	78	9.9	8.1	9.1	+0.8	....	1,740	2,000	7.23	6.80
5/21/20	1,914	220	86	8.3	7.6	8.6	-0.3	62.0	2,135	2,000	7.40	7.29
5/22/20	2,248	238	123	4.9	7.6	8.6	-3.7	....	2,135	2,000	7.66	7.29
5/23/20	1,998	248	93	4.6	5.6	6.6	-2.0	....	2,155	2,000	6.85	8.32
5/24/20	2,065	269	93	4.8	5.7	6.7	-1.9	62.3	2,350	2,000	6.94	9.13
5/25/20	1,772	251	67	4.6	5.1	6.1	-1.5	61.3	1,930	2,000	6.87	8.06
5/26/20	2,370	302	113	3.4	5.1	6.1	-2.7	....	2,580	2,000	6.58	11.15
5/27/20	2,510	332	114	3.3	4.3	5.3	-2.0	60.8	2,520	2,000	6.33	10.96
5/28/20	2,498	327	115	3.3	2.5	3.5	-0.2	60.4	1,480	2,000	6.54	5.50
5/29/20	2,555	342	115	3.4	4.3	5.3	-1.9	....	2,380	2,000	6.55	9.26
5/30/20	2,498	327	115	3.3	3.9	4.9	-1.6	59.4	2,455	2,000	6.54	8.59

\* Estimated.

*Comment.*—The tendency to retain nitrogen in the blood in this case is negligible. The nonprotein nitrogen of the blood before beginning the diet was 39.5 mg. per hundred c.c., while on May 20, before the food nitrogen was reduced, the nonprotein nitrogen was only 26 mg. per hundred c.c. The explanation of the loss in weight becomes apparent at once on examination of the intake and output of salt and water. The weight declined as an excess of salt and water were eliminated, and the edema disappeared.

## DISCUSSION OF RESULTS

The results of the observations made in the calorimeter are shown in Table 7. The respiratory quotients are all within normal limits. The average quotient for fasting<sup>25</sup> observations is 0.79, so that there is no evidence of a qualitative change in the combustions as far as the respiratory quotients are concerned.

Regarding quantitative changes in the metabolism, the data are presented from two points of view in Table 8. It is customary to compare the observed heat production of a patient with the theoretical heat production of a normal man of the same surface area. The percentage variation from the average normal metabolism is shown. It will be observed that in only ten of the fifteen cases were there observations which were considered basal; that is, in the condition of complete rest in the fasting state. The conception of the basal metabolism on which this was based implies the minimal metabolism. If the patient had fever at the time of observation it was considered basal only if the temperature was approximately at the lowest part of the diurnal variation. In the case of Robert W., the patient was very quiet at a temperature of about 40 C. This was not considered basal because the temperature was near the peak of the diurnal curve. In the first hour of the observation on Trellis H. the patient was also very quiet at a similar temperature. If one considers these as basal periods then it may be said that the basal metabolism at 40 C. is 28 or 29 per cent. above the average normal. In the ten remaining cases the basal metabolism ranges from 3 per cent. below to 15 per cent. above the average normal. Barbour's three cases lie within this range, so that it appears that the basal metabolism, as conceived above, is but very slightly elevated above that of normal men of the same surface area.

It should be remembered, however, that in losing weight the surface area of the patient has diminished. As far as each individual patient is concerned, the normal metabolism is the metabolism in health. Comparison of the present with the probable normal metabolism has been made and is also shown in Table 8, for each case in which the previous weight of the patient was known. It will be observed that in all cases except one, John S., the average hourly basal heat production observed is equal to or less than the estimated calories per hour for the same patient in health. In the case of John S. the increase is slight.

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25. Not strictly fasting; small standard breakfast, previously referred to,<sup>13</sup> was given. The effect of this may be considered negligible.

TABLE 7.—

Subject, Date, Weight, Surface Area, Linear Formula	Period	End of Period, Time	Carbon Dioxid, Gm.	Oxygen, Gm.	R. Q.	Water, Gm.	Urine N per Hour, Gm.	Indirect Calo- rimetry, Cal.	Heat Elimi- nated, Cal.
Chas. G. .... 5/8/17 52.2 Kg. 1.57 Sq. M.	Prelim.	12:26	....	....	....	....	....	....	....
	1	1:26	22.2	21.0	0.77	30.5	0.30	....	62.2
	2	2:26	22.6	21.0	0.78	30.6	0.30	....	65.7
	Aver.	....	....	....	....	....	....	69.7	....
Chas. G. .... 5/11/17 52.7 Kg. 1.57 Sq. M.	Prelim.	12:10	....	....	....	....	....	....	....
	1	1:10	23.0	20.2	0.83	28.4	0.33	....	66.3
	2	2:10	23.2	21.7	0.78	38.0	0.33	....	77.2
	Aver.	....	....	....	....	....	....	69.8	....
Chas. G. .... 5/14/17 52.4 Kg. 1.57 Sq. M.	Prelim.	11:58	....	....	....	....	....	....	....
	1	12:58	22.5	20.2	0.81	47.7	0.31	....	73.1
	2	1:58	23.0	20.4	0.82	39.7	0.31	....	70.0
	3	2:58	22.9	21.3	0.78	42.7	0.31	....	73.5
	4	3:55	13.8	12.7	....	....	....	....	....
Aver.	....	....	....	....	....	....	68.8	....	
Trellis H. .... 5/9/17 51.7 Kg. 1.57 Sq. M.	Prelim.	11:47	....	....	....	....	....	....	....
	1	12:47	29.7	26.6	0.81	40.1	0.44	98.0	78.4
	2	1:47	26.4	24.2	0.79	33.5	0.44	80.2	74.8
	Aver.	....	....	....	....	....	....	....	....
Robert W. .... 5/25/17 53.4 Kg. 1.57 Sq. M.	Prelim.	11:18	....	....	....	....	....	....	....
	1	12:18	26.3	23.7	0.81	36.5	0.57	....	72.1
	2	1:18	25.6	25.3	0.74	42.1	0.57	....	73.3
	3	2:18	25.2	23.1	0.80	49.4	0.57	....	93.5
Aver.	....	....	....	....	....	....	78.6	....	
Geo. P. .... 5/24/17 58.5 Kg. 1.70 Sq. M.	Prelim.	12:07	....	....	....	....	....	....	....
	1	1:07	23.8	21.8	0.79	32.3	0.27	72.7	66.0
	2	2:10*	25.9	23.4	0.80	32.8	0.27	78.3	69.7
Aver.	....	....	....	....	....	....	....	....	
Spencer C. .... 12/10/19 44.3 Kg. 1.48 Sq. M.	Prelim.	11:41	....	....	....	....	....	....	....
	1	12:41	22.6	18.4	0.89	28.1	....	62.8	54.8
	2	1:41	23.1	19.1	0.88	30.4	....	65.0	58.5
Aver.	....	....	....	....	....	....	....	....	
Edith B. .... 12/17/19 44.6 Kg. 1.53 Sq. M.	Prelim.	12:47	....	....	....	....	....	....	....
	1	1:47	19.5	17.3	0.82	21.9	....	57.9	49.1
	2	2:47	19.8	18.0	0.80	21.6	....	60.2	47.3
Aver.	....	....	....	....	....	....	....	....	
Edith B. .... 12/19/19 45.5 Kg. 1.53 Sq. M.	Prelim.	8:50 p.m.	....	....	....	....	....	....	....
	1	9:50	19.6	19.1	0.75	31.6	....	62.8	61.2
	2	10:50	23.9	21.2	0.82	31.1	....	71.2	60.5
	3	11:50	23.2	21.6	0.78	34.6	....	71.7	71.0
Aver.	....	....	....	....	....	....	....	....	
Edith B. .... 1/6/20 44.0 Kg. 1.53 Sq. M.	Prelim.	2:42 p.m.	....	....	....	....	....	....	....
	1	3:42	22.9	21.0	0.79	27.0	0.07	70.2	59.8
	2	4:42	22.2	20.6	0.78	27.9	0.07	68.9	63.7
	3	5:42	22.6	21.0	0.78	31.0	0.07	70.1	60.1
Aver.	....	....	....	....	....	....	....	....	
Harry G. .... 1/13/20 42.8 Kg. 1.40 Sq. M.	Prelim.	12:38	....	....	....	....	....	....	....
	1	1:38	23.6	21.5	0.80	39.4	....	71.8	78.2
	2	2:38	24.1	22.6	0.77	38.1	....	75.0	71.5
Aver.	....	....	....	....	....	....	....	....	
Joseph D. .... 1/17/20 59.0 Kg. 1.74 Sq. M.	Prelim.	12:12	....	....	....	....	....	....	....
	1	1:12	20.5	17.9	0.83	26.0	0.17	60.4	58.5
	2	2:12	21.8	21.0	0.76	29.8	0.17	69.3	67.9
Aver.	....	....	....	....	....	....	....	....	
Michael O. .... 1/22/20 50.0 Kg. 1.62 Sq. M.	Prelim.	11:50	....	....	....	....	....	....	....
	1	12:50	26.5	25.2	0.76	41.5	0.05	83.8	82.3
	2	1:50	25.7	23.6	0.79	42.5	0.05	79.1	81.6
Aver.	....	....	....	....	....	....	....	....	

—CALORIMETRIC DATA

Direct Calorimetry Rectal Temp., Cal.	Rectal Temp., C.	Average Pulse	Work Adder, Cm.	Non-protein R. Q.	Per Cent. Calories from			Calories per Hour		Remarks
					Protein	Fat	Carbohydrate	Per Kg.	Per Sq. M. Linear	
...	37.8	...	...	...	..	..	..	....	....	Basal
64.4	37.9	...	4.0	...	..	..	..	....	....	
67.0	37.9	...	6.5	...	..	..	..	....	....	
....	....	116	...	0.77	11	70	19	1.34	44.4	
....	38.6	...	...	....	..	..	..	....	....	Falling temperature
57.2	38.4	...	11.0	...	..	..	..	....	....	
68.6	38.2	...	18.0	...	..	..	..	....	....	
....	....	129	...	0.80	13	59	28	1.33	44.5	
....	38.1	...	...	....	..	..	..	....	....	Basal
60.4	37.8	...	2.5	...	..	..	..	....	....	
73.0	37.9	...	7.5	...	..	..	..	....	....	
70.8	37.8	...	8.0	...	..	..	..	....	....	
....	....	118	...	0.80	12	60	29	1.31	43.8	
....	39.7	...	...	....	..	..	..	....	....	Rising temperature
93.1	40.1	...	18.5	0.81	12	56	32	1.90	62.4	
78.8	40.2	...	...	0.80	15	59	26	1.55	51.1	
....	....	90	...	....	..	..	..	....	....	
....	40.1	...	...	....	..	..	..	....	....	High temperature, very quiet
65.9	40.0	...	2.5	...	..	..	..	....	....	
68.2	39.6	...	4.5	...	..	..	..	....	....	
80.5	39.4	...	3.0	...	..	..	..	....	....	
....	....	104	...	0.78	19	73	8	1.47	50.1	
....	37.4	...	...	....	..	..	..	....	....	(* 63 min.) Basal; very quiet; work adder broken
75.4	37.6	...	...	0.79	10	64	26	....	....	
76.6	37.8	...	...	0.80	10	60	30	....	....	
....	....	70	...	....	..	..	..	1.26	43.3	
....	36.6	...	...	....	..	..	..	....	....	Basal
57.8	36.6	...	24.2	....	..	..	..	1.42	42.4	
57.0	36.6	...	1.3	....	..	..	..	1.47	43.9	
....	....	93	...	....	..	..	..	....	....	
....	37.3	...	...	....	..	..	..	....	....	Basal
67.0	37.8	...	23.0	....	..	..	..	1.30	37.8	
67.0	38.3	...	23.0	....	..	..	..	1.35	39.3	
....	....	116	...	....	..	..	..	....	....	
....	39.5	...	...	....	..	..	..	....	....	High fever, restless in last hour, quiet in first hour
71.4	39.8	...	25.0	....	..	..	..	1.38	41.0	
65.5	39.9	...	21.0	....	..	..	..	1.57	46.5	
70.0	39.6	...	58.7	....	..	..	..	1.58	46.8	
....	....	125	...	....	..	..	..	....	....	
....	39.9	...	...	....	..	..	..	....	....	High temperature, coughing
68.5	40.1	...	40.0	0.79	2	68	30	1.04	47.1	
75.0	40.4	...	27.0	0.78	2	73	25	1.56	45.0	
53.1	40.0	...	33.0	0.78	2	72	26	1.60	45.8	
....	....	137	...	....	..	..	..	....	....	
....	39.2	...	...	....	..	..	..	....	....	Observation vitiated by restlessness
69.0	39.0	...	45.0	....	..	..	..	1.68	51.3	
69.7	38.9	...	43.0	....	..	..	..	1.68	51.4	
....	....	120	...	....	..	..	..	....	....	
....	37.2	...	...	....	..	..	..	....	....	Afebrile, basal, moved in last 4 min. of last period
58.2	37.2	...	39.5	0.84	8	52	40	1.02	34.7	
70.5	37.2	...	50.0	0.75	7	77	16	1.17	39.9	
....	....	82	...	....	..	..	..	....	....	
....	39.8	...	...	....	..	..	..	....	....	Restless, coughing
65.2	39.4	...	43.0	0.76	2	80	18	1.68	51.7	
4.4	39.2	...	36.0	0.79	2	70	28	1.58	48.8	
....	....	120	...	....	..	..	..	....	....	

TABLE 7.—CALORIMETRIC—

Subject, Date, Weight, Surface Area, Linear Formula	Period	End of Period, Time	Carbon Dioxid, Gm.	Oxygen, Gm.	R. Q.	Water, Gm.	Urine N per Hour, Gm.	Indirect Calo- rimetry, Cal.	Heat Elimi- nated, Cal.
Anna H. .... 2/5/20 41.0 Kg. 1.41 Sq. M.	Prelim.	12:25	....	....	....	....	....	....	....
	1	1:25}	....	....	....	....	....	....	....
	2	2:25}	45.5	47.3	0.76	62.9	0.46	143.9	138.2
	Aver.	.....	....	....	....	....	....	....	....
John H. .... 2/10/20 45.5 Kg. 1.53 Sq. M.	Prelim.	11:50	....	....	....	....	....	....	....
	1	12:50	21.6	20.1	0.78	37.5	....	66.8	69.0
	2	1:55*	23.9	23.7	0.73	35.3	....	77.8	71.9
	Aver.	.....	....	....	....	....	....	....	....
John H. .... 2/12/20 45.1 Kg. 1.53 Sq. M.	Prelim.	11:54	....	....	....	....	....	....	....
	1	12:54	24.1	23.4	0.75	34.6	0.42	76.6	71.6
	2	1:54	25.5	25.1	0.74	40.3	0.42	82.2	77.7
	3	2:54	26.5	26.5	0.73	43.6	0.42	86.5	81.7
	Aver.	.....	....	....	....	....	....	....	....
John H. .... 3/1/20 44.9 Kg. 1.53 Sq. M.	Prelim.	1:10	....	....	....	....	....	....	....
	1	2:19	21.4	21.6	0.72	30.6	....	70.5	63.9
John H. .... 4/14/20 44.7 Kg. 1.53 Sq. M.	Prelim.	1:22	....	....	....	....	....	....	....
	1	2:22	19.9	17.8	0.82	48.9	....	59.6	75.2
	2	3:22	20.8	20.0	0.76	47.2	....	66.3	69.6
	Aver.	.....	....	....	....	....	....	....	....
Wm. H. .... 3/2/20 50.3 Kg. 1.53 Sq. M.	Prelim.	12:15	....	....	....	....	....	....	....
	1	1:15	23.0	21.5	0.78	34.9	0.34	71.2	76.6
	2	2:15	23.2	22.6	0.75	33.8	0.34	74.2	75.5
	Aver.	.....	....	....	....	....	....	....	....
Wm. H. .... 3/10/20 49.7 Kg. 1.53 Sq. M.	Prelim.	12:00	....	....	....	....	....	....	....
	1	1:00	20.8	19.4	0.78	31.4	0.30	64.4	72.1
	2	2:00	21.5	20.2	0.78	30.3	0.30	66.8	70.6
	Aver.	.....	....	....	....	....	....	....	....
Wm. H. .... 3/11/20 49.7 Kg. 1.53 Sq. M.	Prelim.	11:27	....	....	....	....	....	....	....
	1	12:27	21.8	21.0	0.75	40.0	0.65	68.7	73.1
	2	1:27	24.0	22.5	0.77	32.4	0.65	73.9	70.5
	3	2:27	27.4	26.3	0.76	33.9	0.65	86.1	76.1
	Aver.	.....	....	....	....	....	....	....	....
John S. .... 3/17/20 62.3 Kg. 1.88 Sq. M.	Prelim.	12:37	....	....	....	....	....	....	....
	1	1:37	26.9	22.9	0.86	41.4	....	77.6	83.6
	2	2:37	27.1	28.0	0.71	51.9	....	91.5	92.3
	Aver.	.....	....	....	....	....	....	....	....
Geo. M. .... 3/24/20 49.2 Kg. 1.53 Sq. M.	Prelim.	11:20	....	....	....	....	....	....	....
	1	12:20	26.1	24.3	0.78	41.5	....	80.8	81.2
	2	1:22*	25.1	22.6	0.81	48.0	....	78.1	90.4
	Aver.	.....	....	....	....	....	....	....	....
Geo. M. .... 3/26/20 48.9 Kg. 1.53 Sq. M.	Prelim.	11:22	....	....	....	....	....	....	....
	1	12:22	27.4	23.1	0.86	43.9	....	78.4	80.0
	2	1:22	25.8	23.2	0.81	61.6	....	77.5	101.6
	Aver.	.....	....	....	....	....	....	....	....
Joseph R. .... 5/25/20 61.3 Kg. 1.74 Sq. M.	Prelim.	12:27	....	....	....	....	....	....	....
	1	1:27	23.5	21.2	0.81	29.7	0.20	71.0	60.5
	2	2:27	23.1	21.1	0.80	29.5	0.20	70.4	64.1
	Aver.	.....	....	....	....	....	....	....	....

—DATA—(Continued)

Direct Calorimetry Rectal Temp., Cal.	Rectal Temp., C.	Average Pulse	Work Adder, Cm.	Non-protein R. Q.	Per Cent. Calories from			Calories per Hour		Remarks
					Protein	Fat	Carbohydrate	Per Kg.	Per Sq. M. Linear	
....	39.4	...	21.0	...	..	..	..	....	....	Fairly quiet
146.3	{ 39.5 39.6	...	21.0	0.74	17	73	10	....	....	
....	....	132	....	....	..	..	..	1.76	51.1	
....	37.4	...	....	....	..	..	..	....	....	(* 65 min.) Basal
65.2	37.3	...	8.5	....	..	..	..	1.47	43.7	
74.6	37.4	...	11.0	....	..	..	..	1.57	46.7	
....	37.9	...	....	....	..	..	..	....	....	350 gm. meat given 1 hour before start
72.0	37.9	...	30.0	0.74	15	75	10	1.70	50.0	
79.5	38.0	...	20.0	0.73	14	79	7	1.82	53.7	
84.2	38.1	...	37.0	0.72	13	57	30	1.92	56.5	
....	....	93	....	....	..	..	..	....	....	Basal
64.6	38.7	...	18.0	....	..	..	..	1.57	46.1	
....	37.8	...	....	....	..	..	..	....	....	Basal
60.5	37.4	...	3.0	....	..	..	..	1.33	39.0	
72.4	37.5	...	11.0	....	..	..	..	1.48	43.3	
....	....	104	....	....	..	..	..	....	....	Basal in first hour, coughing in second hour
76.3	38.6	...	18.5	0.78	13	67	20	1.41	46.5	
75.9	38.6	...	35.5	0.74	12	78	10	1.47	48.5	
....	....	80	....	....	..	..	..	....	....	Basal
72.2	38.0	...	8.5	0.78	12	68	20	1.32	42.1	
71.0	38.0	...	11.0	0.77	12	69	19	1.49	48.5	
....	37.6	...	....	....	..	..	..	....	....	350 gm. meat given 1 hour before start
64.0	37.4	...	3.5	0.74	23	70	7	1.38	44.9	
76.3	37.5	...	14.0	0.76	20	65	15	1.49	48.3	
88.1	37.8	...	24.0	0.75	25	66	9	1.73	56.3	
....	....	85	....	....	..	..	..	....	....	Basal
83.7	37.8	...	....	....	..	..	..	....	....	
69.4	37.4	...	10.0	....	..	..	..	1.25	41.3	
....	....	114	32.0	....	..	..	..	1.47	48.7	(* 62 min.) Falling temperature, restless
74.5	39.6	...	....	....	..	..	..	....	....	
61.8	39.4	...	25.0	....	..	..	..	1.64	52.8	
....	38.7	...	30.0	....	..	..	..	1.46	48.1	Rapid fall of temperature, restless
....	....	94	....	....	..	..	..	....	....	
63.3	39.2	...	....	....	..	..	..	....	....	
74.2	38.8	...	40.0	....	..	..	..	1.60	51.2	
....	38.2	...	40.0	....	..	..	..	1.59	50.6	Basal
....	....	84	....	....	..	..	..	....	....	
62.2	36.7	...	17.0	0.81	8	60	32	1.16	40.8	
58.7	36.7	...	12.0	0.80	8	64	28	1.15	40.5	....
....	....	88	....	....	..	..	..	....	....	

In the remaining observations, which were not basal, it will be observed in Table 8 that the heat production may be considerably increased by coughing, restlessness and by high fever. The increase in metabolism is usually due to several factors combined and it is, of course, impossible to evaluate each factor. The greatest increase in any single hour reached 43 per cent. above the average normal in the case of Trellis H., whose temperature was over 40 C. and who was coughing. In one observation on William H. the temperature remained stationary at 38.6 C. during two hours in the first of which

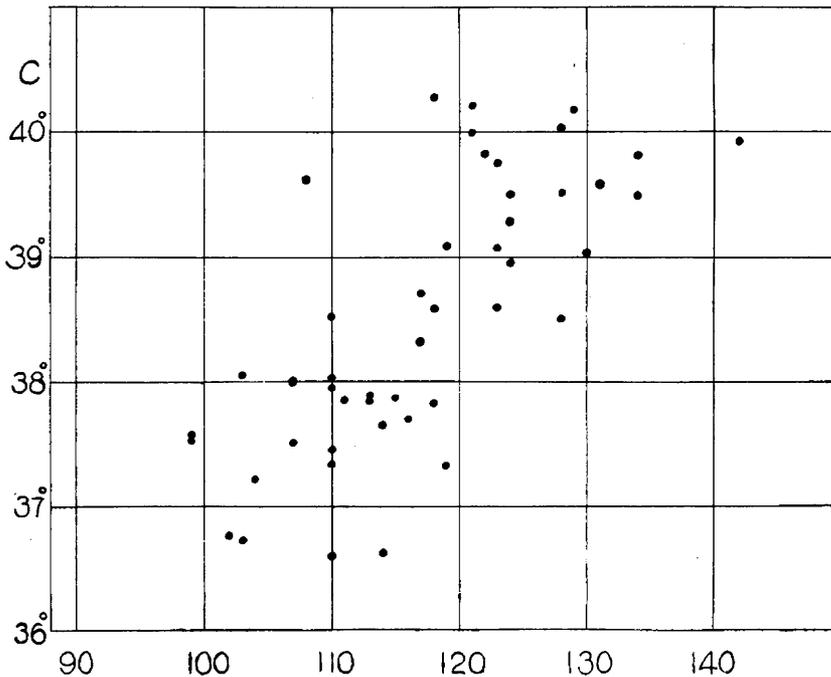


Fig. 13.—Relationship of body temperature and heat production in tuberculosis. The metabolism, during a short period, expressed in terms of percentage of average normal (100 per cent.) is plotted against the mean rectal temperature for the same period, which was usually one hour.

the patient was very quiet and the metabolism was 18 per cent. above the average normal. In the second hour he was likewise very quiet but coughed considerably, with the result that a further increase of 5 per cent. in metabolism occurred.

In Figure 13 an attempt has been made to evaluate the effect of body temperature on the heat production. In the figure the spots represent the percentage of average normal metabolism in a given period, usually one hour, plotted against the average rectal temperature for the period. The grouping of these points suggests the

general tendency of an increased body temperature to increase the heat production. In the case of Robert W. the patient was very quiet at a temperature ranging between 40.1 and 39.4 C., the metabolism being 29 per cent. above average normal. Also, in one hour Trellis H. was very quiet, with a temperature of from 40.1 to 40.2 C., his metabolism being 29 per cent. above average normal. In these two cases the effect of temperature is uncomplicated.

In Figure 14 there is a graphic representation of the relationship of heat produced in the body to the heat eliminated from the body in five cases, chosen to illustrate different phases of temperature change. In the case of Edith B., the temperature rose from 37.3 C. to 38.3 C. during two hours, without a chill. It will be observed that during this rise of 1 degree the heat production rose only a little over two calories per hour. During the first hour the heat eliminated was 9 calories less than the heat produced, and during the second hour the elimination of heat was about 2 calories less than in the first, still further increasing the storage of heat.

The question of the mechanism of temperature changes in the body is of great interest. A review of the literature on this subject will be found in a paper by Barr and Du Bois.<sup>26</sup> In the metabolism of malaria the rise in temperature was accompanied by a chill and a part of the rise in heat production may therefore be attributed to the muscular work of shivering. The case of Edith B., therefore, may be contrasted with the malarial paroxysm, since in her case the rise was not accomplished by a chill, nor by much increase in metabolism, the heat radiated being reduced. Referring again to Figure 14, it will be noticed that on a subsequent occasion with a much higher temperature her metabolism during the first hour showed almost no further increase over that of the first observation. During the second and third hours she was coughing and restless. These observations show that increases in metabolism due to elevation of body temperature, per se, may not be large.

In this same observation and in a subsequent one on the same patient the peak of the rise in rectal temperature was included. Though the rectal temperature had started to drop in the third hour of each experiment, the heat eliminated from the body had not yet exceeded the heat produced. Thus, it appears that for a short time, at least, the average body temperature was still rising after the rectal temperature began to fall.

The fourth observation, graphically presented in Figure 14, shows a rapid fall of temperature with sweating. Here the heat lost greatly

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26. Barr, D. P., and Du Bois, E. F.: *The Metabolism in Malarial Fever*, *Arch. Int. Med.* **21**:627 (May) 1918.

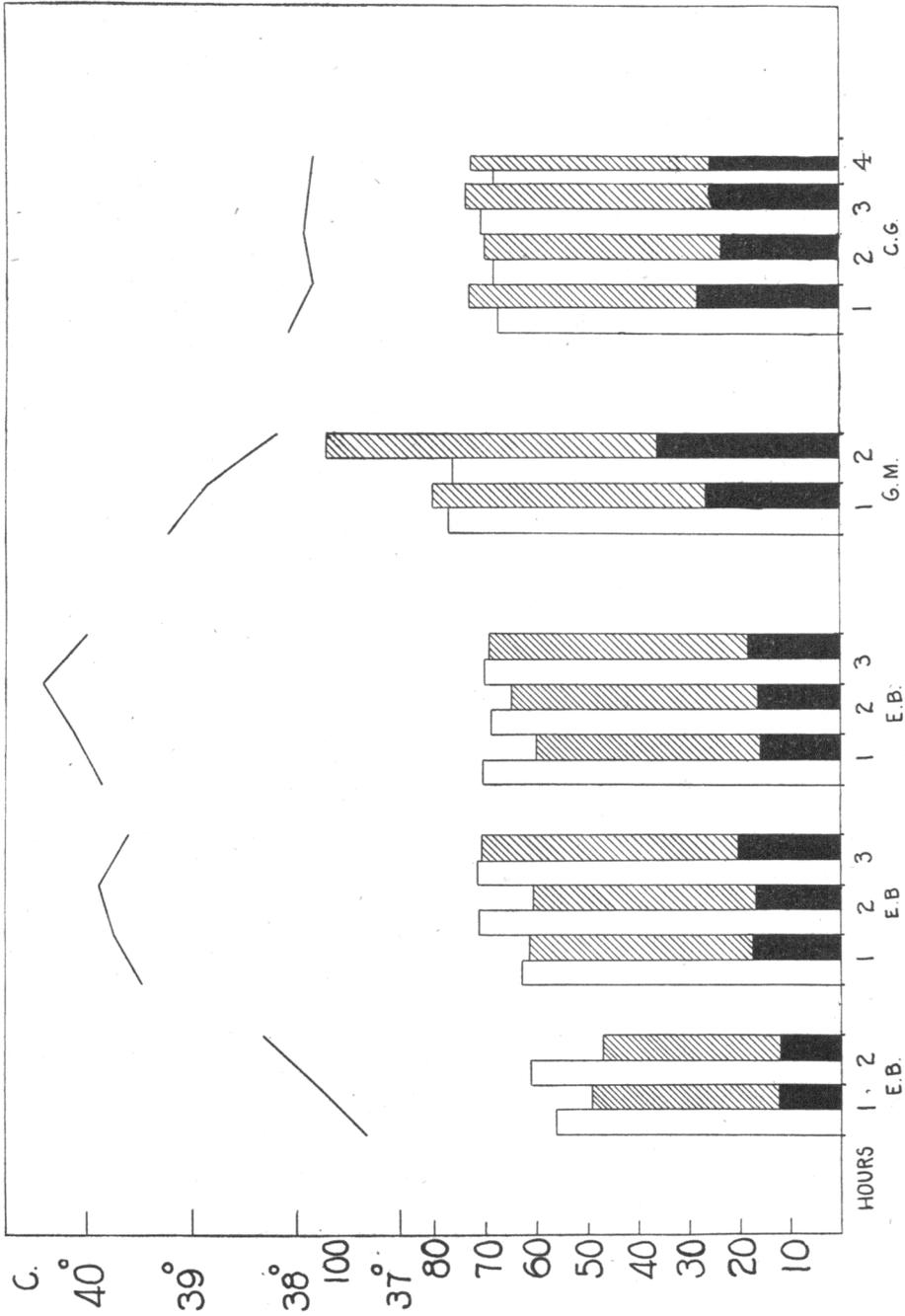


Fig. 14.—Relationship of heat production and heat elimination during rise and fall of rectal temperature. Five observations on three individuals. Lines show rectal temperature in degrees C. Unshaded columns represent calories per hour produced in the body, determined by the indirect method. Shaded columns represent heat lost from the body by vaporization of water (solid black) and by radiation (hatched). Periods are one hour for each pair of columns.

exceeded the heat produced, and the average body temperature fell with the rectal temperature. In this observation a great increase occurred in the number and percentage of calories lost by vaporization of water from the skin and lungs. Du Bois<sup>27</sup> has shown that under ordinary circumstances the water elimination from these sources requires about 25 per cent. of the total heat for its vaporization. In the case of George M. the percentage was between 32 and 35. In the observation of Charles G., shown in the same figure, the latent heat of vaporization amounts to 38 per cent. of the total. This observation was made at the end of a fall in temperature and it will be noted that the average body temperature continued falling after the rectal temperature had become almost stationary. These observations show that the rectal temperature is not an entirely reliable index of changes of the average body temperature and that the absolute relation between the two remains unknown.

In this connection it should be pointed out that the heat produced, as calculated in the direct calorimetry, is equal to the heat eliminated plus or minus the body change correction. This body change correction is estimated by multiplying the change in rectal temperature in degrees centigrade by the specific heat of the body (0.83) times the body weight in kilograms. For the year 1919-1920 the total number of calories measured indirectly was 6,511.73, the total heat eliminated was 6,441.60 calories, while the total heat produced measured by the direct calorimetry, corrected for changes in rectal temperature, was 6,167.37. Such a discrepancy may be accounted for partly by the lack of parallelism between the rectal and average body temperatures and the fact that the total fall in rectal temperature exceeded the total rise.

#### THE SPECIFIC DYNAMIC ACTION OF PROTEIN IN TUBERCULOSIS

Two of the patients in this series were given a meal of meat in order to study the effect of the protein on the heat production. Various meals have been used in the past for this purpose, but in the present instance the meal consisted of 350 gm. of lean beef, ground, pressed into balls, and cooked in 10 gm. of butter. This gave 70 gm. of protein, 28 gm. of fat and 547 total calories. The observation in each case was started one hour after the middle of the meal and continued for three hours. The rise in heat production compared with the basal heat production is shown graphically in Figure 15.

The average increase in metabolism per hour for three hours was 16.1 per cent. in the case of William H. and 18.4 per cent. in

27. Soderstrom, G. F., and Du Bois, E. F.: The Water Elimination Through the Skin and Respiratory Passages, *Arch. Int. Med.* **19**:931 (June) 1917.

the case of John H. In the first case the extra heat in the fourth hour after eating amounted to 31 per cent. of the basal metabolism and in the second case to 25 per cent. The effect of the same meal has been studied on three normal men. So far, the behavior of the tuberculous patients has differed in no way from that of normals. Further study of the effect of this protein meal, both on tuberculous and normal subjects, will be the subject of a later communication.

With the normal subject with the same meal the average percentage increases in the second, third and fourth hours, respectively, were 16, 24 and 24 per cent. The average increase per hour was 21 per cent. There were considerable variations among the normals studied, probably due to differences in the rate of digestion and absorption. The effect of the meal has been observed on one normal to the end of the fifth hour after eating, in which the metabolism

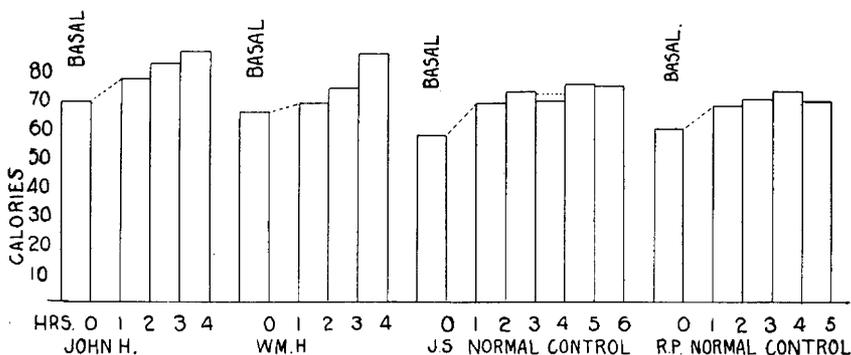


Fig. 15.—Effect of a protein meal on the heat production.

was still 30 per cent. above the basal level, with an average hourly increase of 25 per cent. It seems probable that the effect of the meal would persist for from nine to ten hours at least.

It is to be remembered that Coleman and Du Bois<sup>28</sup> found very little specific dynamic action of protein in febrile typhoid patients. They point out that the protein metabolism was at high level at the time of the basal observation, due to the influence of the disease, and that the protein ingested merely served to replace protein already breaking up in increased quantity, and such protein would not serve to increase the heat production. The fact that a specific dynamic rise has been noted in tuberculosis is further evidence that the toxic destruction of protein is less than in typhoid fever.

28. Coleman, Warren, and Du Bois, E. F.: Calorimetric Observations on the Metabolism of Typhoid Patients With and Without Food, *Arch. Int. Med.* **15**: Pt. 2, 940 (May) 1915.

## THE PROTEIN MINIMUM IN TUBERCULOSIS

The minimum protein requirement in tuberculosis probably depends, as in health, on the size of the "wear and tear" quota and an adequate supply of nonprotein foodstuffs. Investigations of other infections have shown generally an increase in protein destruction due to the toxins of the disease. Some evidence<sup>2</sup> has been given regarding the extent of this toxic destruction, which indicates that it is small but of importance because of the great duration of the disease.

The work of Chittenden, Sivén, Kumagawa and many others<sup>29</sup> indicates that the protein metabolism of normal men may be reduced to a very low level. More recently Sherman<sup>30</sup> has found from 0.633 to 0.637 gm. of protein per kilogram of body weight per diem to be adequate for the maintenance of normal men.

In typhoid fever Kocher<sup>31</sup> has studied the toxic destruction of protein by giving to a patient a diet containing carbohydrate in large amounts and very little protein. He found it impossible, during the febrile period, to reduce the protein metabolism to the low level of the normal "wear and tear" quota.

In four of the cases of our series, observations were made which were somewhat similar to those of Kocher. The estimated daily basal requirement for each case is given in Table 8. The records of the amounts of food given and of the nitrogen balances are to be found in Tables 3 to 6, inclusive, and are shown graphically in Figures 16 to 19, inclusive. In general, the procedure was to give the patient a diet slightly in excess of the basal energy requirement, containing between 10 and 15 gm. of nitrogen per diem for a period of five or six days. The nitrogen intake was then reduced, with a simultaneous increase in the amount of fat and carbohydrate.

The data obtained in these four cases are insufficient to establish the minimum requirement of protein for tuberculous patients. They will serve as a starting point for work of a similar nature, on which a later report will be made. In general it may be said that when the food nitrogen was reduced to the low level of from 3 to 3.5 gm. per diem, with the addition of from 600 to 900 calories to the basal requirement, the urinary nitrogen excretion fell to the level of 5 or 6 gm. per diem, the patient remaining in negative nitrogen balance. This indicates a "wear and tear" quota greater than normal. The minimum nitrogen excretion noted by Kocher<sup>31</sup> in a typhoid patient was somewhat higher (10.4 gm. during fever, from 5.8 to 6.7 gm. beginning convalescence) and was obtained at the expense of much

29. Chittenden, Russell H.: *Physiological Economy in Nutrition*, 1914.

30. Sherman, H. C.: *Protein Requirement in Maintenance of Man*, *J. Biol. Chem.* **41**:97, 1920.

31. Kocher: *Deutsch. Arch. f. klin. Med.* **115**:106, 1914.

more carbohydrate and fat. A toxic destruction of protein exists, therefore, in tuberculosis but to less extent than in typhoid fever.

In view of the results in these four cases, it seems probable that many febrile, tuberculous patients may be kept in nitrogen balance on diets containing from 60 to 70 gm. of protein per diem. The

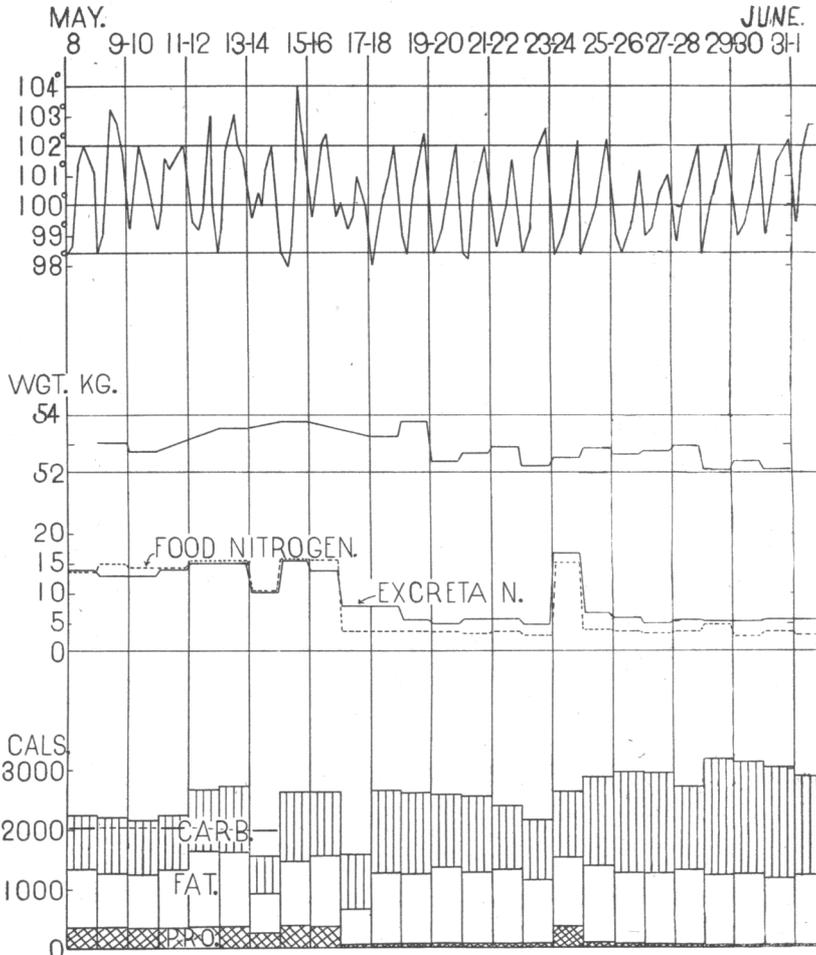


Fig. 16.—Diet chart and nitrogen balance, Charles G.

amount of protein is much less than Voit's standard allowance (118 gm.) for normal men, though somewhat greater than the normal minima of Chittenden and of Sherman (from 35 to 45 gm.). It is much less than is fed to patients in many of the sanatoria for tuberculosis.

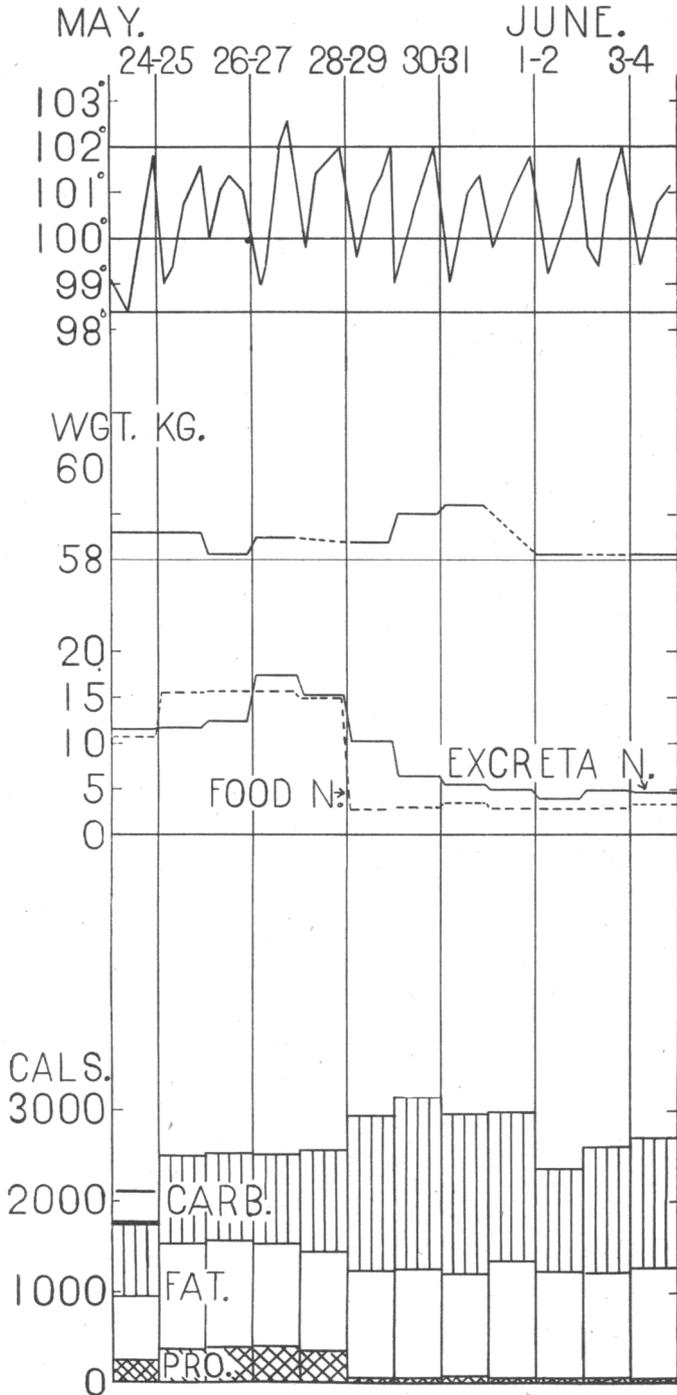


Fig. 17.—Diet chart and nitrogen balance, George P.

## PRACTICAL CONSIDERATIONS REGARDING DIET IN TUBERCULOSIS

The importance of rest during periods of activity of pulmonary tuberculosis has been generally recognized. By artificial pneumothorax, by rest, by control of the cough, the volume of the respiratory exchange and of the total ventilation is reduced. This seems to be a desirable end for which to strive during the period of encapsulation of the foci of the disease. It does not seem to have occurred to the practitioner that an increase in metabolism due to the specific dynamic action of protein will have the same effect on the respiratory exchange as a similar increase due to muscular work.

TABLE 8.—SUMMARY OF CALORIMETER DATA

Name	Weight in Health, Kg.	Surface in Health, Sq. M.	Estimated Calories per Hour in Health	Present Calories per Hour Observed	Present Surface Area, Sq. M.	Metabolism Variation from Aver. Normal per Cent.	Calories per 24 Hours	Remarks
Chas. G. ....	....	....	....	69.5	1.56	+13	1,668	Basal
Trellis H. ....	....	....	....	84.4	1.57	+35	2,026	Fever, 40 C.; cough
Robert W. ....	....	....	....	78.6	1.57	+29	1,886	40.1-39.4 C., quiet
Geo. P. ....	69.5	1.84	75.4	75.5	1.70	+11	1,812	Basal
Spencer C. ....	74.0	1.85	71.2	63.9	1.48	+12	1,584	Basal
Edith B. ....	61.5	1.77	66.4	59.0	1.53	+ 2	.....	Basal, afebrile
				66.6	1.53	+15	1,598	Fever, restless
Harry G. ....	56.0	1.60	68.8	73.5	1.40	+21	1,746	Fever, restless
Joseph D. ....	61.3	1.75	67.4	64.9	1.74	- 3	1,558	Basal
Anna H. ....	51.0	1.55	62.0	72.0	1.41	+28	1,728	Fever, coughing
Mich. C. ....	59.0	1.74	68.7	81.5	1.62	+27	1,956	Fever, coughing
John H. ....	64.5	1.78	70.3	69.9	1.53	+15	1,678	Basal, febrile
				63.0	1.53	+ 5	1,512	Basal, afebrile
Wm. H. ....	61.0	1.67	66.0	65.6	1.54	+ 9	.....	Basal, 38 C.
				72.7	1.53	+21	1,658	Coughing, 38.6 C.
John S. ....	76.0	2.04	80.6	84.6	1.88	+14	2,030	Basal
Geo. M. ....	62.3	1.69	66.8	77.6	1.53	+28	1,862	Fever, restless
Joseph R. ....	82.0	1.98	78.4	70.7	1.74	+ 3	1,697	Basal
J. D. ....	....	....	....	61.8	1.50	+ 4	1,483	H. G. Barbour's case
G. G. ....	....	....	....	62.4	1.54	+ 3	1,598	Same
S. L. ....	....	....	....	67.2	1.63	+ 4	1,613	Same

\* Average of two operations.

During periods of acute activity of the disease it may be well to limit the protein intake and the total calories fed to patients to the minimum necessary to maintain nitrogen equilibrium without regard to the weight of the patient. Later, when acute symptoms have subsided, and when there is evidence that the natural barriers against the disease are established, a more liberal diet could be given with less fear of the effects of an increased respiratory activity.

An excellent article has just appeared, by Janney and Newell,<sup>32</sup> on the relationship of tuberculosis and diabetes. These authors point out that the course of pulmonary tuberculosis, complicating

32. Janney, N. W., and Newell, R. R.: Treatment of Diabetes Complicated by Pulmonary Tuberculosis, J. A. M. A. 75:153 (July 17) 1920.

diabetes, does not seem to be influenced unfavorably by the state of undernutrition resulting from a rigid adherence to the proper diabetic diets, but quite the reverse. They show that among diabetic patients the mortality rate from tuberculosis has diminished markedly since the inauguration of the Allen treatment. Similar experience has also been recorded by Joslin.<sup>33</sup> In their own series of cases the development of tuberculosis seems always to have commenced during periods in which diabetic patients were living on a liberal and uncontrolled dietary. In view of these facts no unfavorable results are to be expected from temporary dietary restrictions in nondiabetic tuberculous patients.

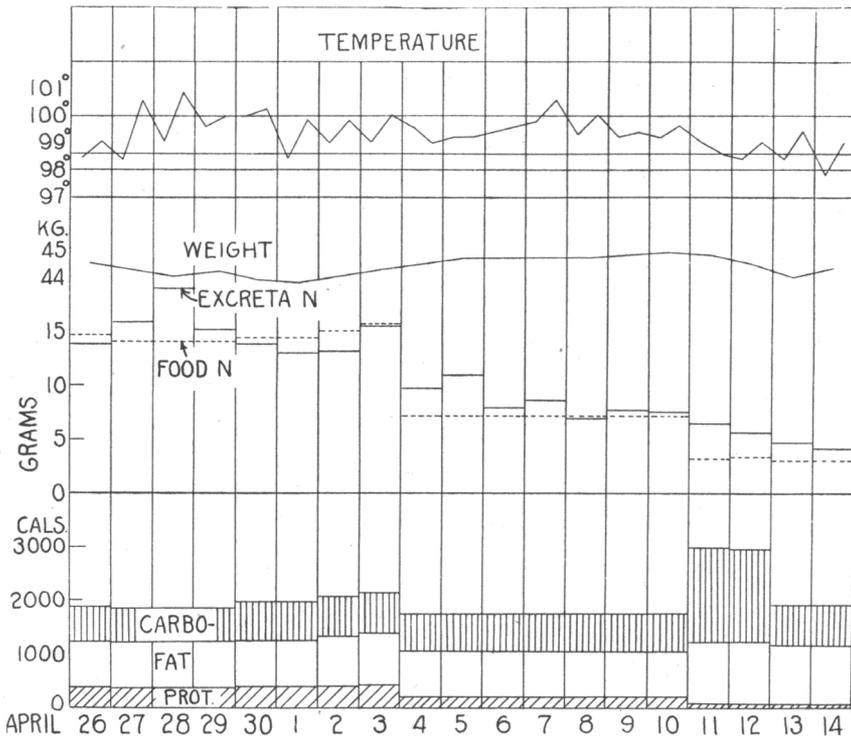


Fig. 18.—Diet chart and nitrogen balance, John H.

In Table 8 estimates of the daily heat production of patients in this series are given. These range from 1,500 to 2,000 calories per day for rest in bed and the fasting state. During periods of activity of a pulmonary tuberculosis the diet need not contain more than 500 calories above the basal requirement (from 2,000 to 2,500 calories), nor more than 60 gm. of protein. The object of such a diet is to maintain the respiratory activity at the lowest level compatible with

33. Joslin: The Treatment of Diabetes Mellitus, 1916.

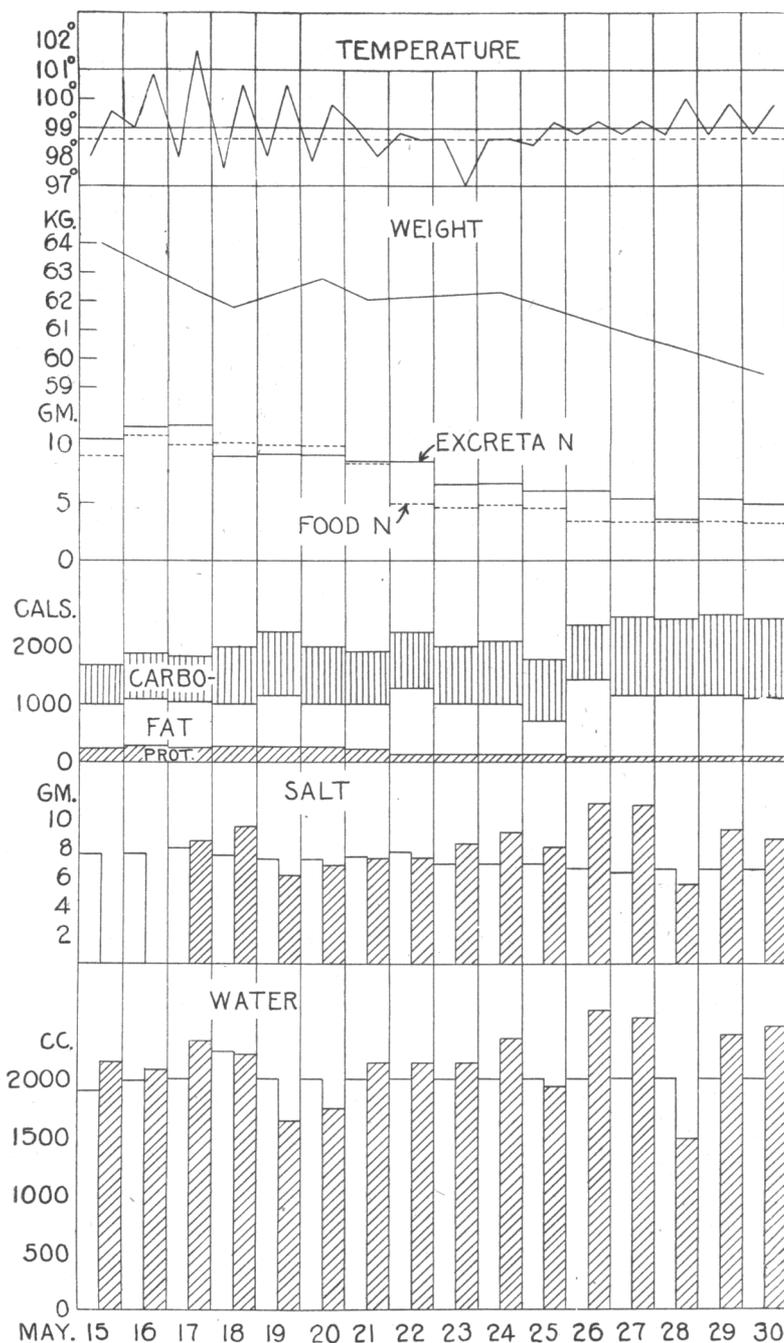


Fig. 19.—Diet chart and nitrogen balance, Joseph R. Water formed by combustion and that eliminated from skin and lungs was not included in the measurement of water balance. Water and salt output in shaded columns. Intake unshaded.

the maintenance of nitrogen equilibrium. To achieve this purpose it is just as necessary not to overfeed as it is to maintain muscular rest.

When the activity of the disease has subsided the total calories in the diet should be raised to meet the requirements of the patient as his muscular activity increases. The protein intake could also be increased to enlarge the repair quota.

#### SUMMARY

1. The basal metabolism of tuberculous patients may be normal or very slightly above that of normal men of the same size. Thus, in ten cases, the variation from average normal was from minus 3 to plus 15 per cent.

2. Further increases in metabolism occur with a rise of body temperature. These increases are not large. Thus one case was given in which the temperature rose 1 degree C. during two hours without a chill. The heat production of the second hour was only two calories greater than that of the first hour. With a rectal temperature of 104 F., (40 C.) the metabolism may be 30 per cent. above the average normal.

3. The basal heat production in tuberculosis may be less than the normal for the same patient when in health; in other words, the loss in weight may be accompanied by a reduction in metabolism which more than compensates for the tendency to increase caused by the disease.

4. Limited data regarding the nitrogen excretion show that, while a toxic destruction of protein does exist in tuberculosis, it is not large. The urinary nitrogen may be reduced to from 5 to 6 gm. per diem, though nitrogen balance may be attained only at a higher level (about 10 gm. a day).

5. The specific dynamic rise in metabolism produced in two cases by the ingestion of a protein meal corresponded closely with that produced by the same meal in three normal men.

#### CONCLUSIONS

In view of the fact that the food requirements of tuberculous patients are not large, either as regards total energy value or nitrogen content, forced feeding is unnecessary and is probably harmful in the active stages of pulmonary disease. Since protein increases the respiratory exchange in the tuberculous as in normals it may be well to limit the protein intake during periods of activity (of the disease) in order to put the lungs at rest.