YOUNG

THE METABOLISM OF WHITE RACES LIVING IN THE TROPICS

I.—THE PROTEIN METABOLISM

BY

W. J. YOUNG

FROM THE BIOCHEMICAL LABORATORY, THE AUSTRALIAN INSTITUTE OF TROPICAL MEDICINE, TOWNSVILLE, N. QUEENSLAND.

(*Received for publication 2 November*, 1914)

The effect of high temperature and a moist atmosphere upon the metabolism of the human body has been studied by workers in temperate climates, the conditions being artificially produced in a specially constructed chamber, and also by a few investigators who carried out experiments upon both acclimatised whites and natives living in the Tropics. In almost every case attention has been given to the total exchanges of the body, with the object of ascertaining whether the altered conditions bring about the introduction of any new factor into the mechanisms by which the body regulates its thermal equilibrium.

The most important investigations done in the Tropics were those of Eijkman in 1893, who determined the calorific value of the everyday food of a number of white men living in Java, and found that the average did not differ from that usually accepted as a standard in Europe. Examination of the food of Malays also showed that the heat value per kilogram of body weight was not materially different from that of the white men. In these researches balance sheets were drawn up between the total nitrogen taken in and that excreted, but no investigations were made into the separate nitrogenous products of protein metabolism.

A number of analyses of the nitrogenous constituents of the urine were made by McCay (1908) in India, but were confined to an examination of the urines of Bengalis, a people who conform to a diet with much lower protein content than Europeans

In the course of a study of the effect of residence in tropical countries upon a working white race, it was thought that some information might be obtained by a fairly complete examination of the partition of the nitrogen and sulphur excreted in the urine. The significance of the different excretory substances in urine is but very imperfectly understood, and the effect of any departure from normal conditions is of interest from the possibility of throwing light upon the processes which constitute the nitrogenous metabolism of the body.

The principal product by which proteins give up their nitrogen in the body is urea, and the bulk of this substance appearing in the urine represents the ammonia produced by deaminisation of nitrogenous foodstuffs. It tells us nothing as to what has happened to the remainder of the molecule from which it has been derived.

Certain substances, however, appear to be produced by the metabolism of the tissues, the endogenous metabolism of the body. Thus, the creatinine is almost entirely derived from this source, since the quantity of creatinine excreted on a low protein diet is practically the same as when the diet is rich in nitrogen (Folin). Only a small fraction is due to creatine taken in with the food. Leathes (1907) found that during fever, when the tissue metabolism is known to be increased, the quantity of creatinine in the urine was also increased, and recent experiments on rabbits by Meyers and Volovic (1913) have confirmed this observation, and have shown that the output of creatinine is increased whether the pyrexia be caused by infection or by confining the animal in a hot atmosphere.

The total quantity of sulphur contained in the urine normally runs parallel to nitrogen, varying with the quantity and nature of the protein catabolised. The bulk of the sulphur is excreted in the fully oxidized form as inorganic sulphates, together with a small quantity in combination with indol and skatol as ethereal sulphates, these products being the result of bacterial decomposition in the intestine. A small quantity of sulphur is excreted in an unoxidized form, termed neutral sulphur, which in all probability consists mainly of cystine and thiocyanates. The output of neutral sulphur in normal individuals was found by Folin to be independent of the quantity of protein in the diet, and for this reason he considered

this portion of the sulphur as derived, like the creatinine, from endogenous sources.

From the experiments on creatinine mentioned above, it seemed possible that tissue metabolism might take place to a greater extent in a tropical climate, and it was of special interest to find whether the quantity of the substances derived from this source was very different from the averages in urines of residents in temperate climates.

Fairly complete analyses were made of the daily urine of four male subjects ranging in age from 25 to 36 years, and who had resided in Tropical Queensland from one to four years. The experiments extended in most cases over a week, the total urine being collected and each twenty four hours' sample analysed. The subjects were living an ordinary laboratory life, were allowed to choose their own diet, as the aim was to make the observations under the conditions of every day life. Moreover, most investigators are agreed that the knowledge of the diet being controlled is not without influence on the quantity of food taken, whilst if a fixed diet be partaken, the continued sameness affects the appetite. As a preliminary, therefore, the diets were uncontrolled as regards quantity and character, excepting in one case (protocol IV) where the subject was taking a milk and bread diet of known nitrogen content.

In addition to these four experiments, determinations have been made at different times of the total nitrogen and the creatinine in the daily urine of five subjects, and in two cases comparisons have been made of the quantities of these substances excreted during the hot rainy season and the cooler dry season.

METHODS

The total nitrogen was determined by Kjeldahl and urea by Folin's (1912) potassium acetate method, uric acid by the Folin Schafer method and the purin bases were estimated after precipitating the uric acid as recommended by Kennaway (1909).

For the estimation of creatinine Folin's well-known method was employed, but some modification was required on account of the high temperature of the laboratory. Although numerous papers have been published on the conditions under which this determination should be carried out, such as the quantities of reacting fluids, the time during which the solutions are allowed to react, the temperature and the extent of dilution before the readings are made, all such conditions have been determined for room temperatures about 15-20° C. In this laboratory, during the hot season, the air temperature during the day is rarely below 27° C. and generally ranges from 30 to 35°, whilst that of the water supply is usually about 30°. The conditions laid down by other workers were, therefore, not applicable, and had to be readjusted to meet the requirements. For this purpose a solution containing 10 mgms. of creatinine in the form of the picrate (mpt. 205-206°) in 20 c.c. was employed, and the depth of colour produced by the addition of alkali and picric acid compared with a 0·1N solution of potassium bichromate in the Dubosq colorimeter in the usual manner. Experiments were also carried out with urine. It is only necessary here to give the conditions established, without going into the experimental details. It was found that at temperatures between 27° and 35° C., 10 mgms. of creatinine gave the maximum coloration within four minutes, whilst the colour faded if the reacting liquids were allowed to stand for longer than six minutes. The best quantities of the reagents were 15 c.c. picric acid (saturated solution) and 5 c.c. of 10 % sodium hydroxide, the whole being diluted to 500 c.c. as recommended by Folin. Within limits the total volume of the reacting fluids did not influence the colour, thus 5 c.c. of urine diluted either to 10 or 20 c.c. gave the same reading. The colour of the diluted mixture was found to fade fairly quickly, the solutions were therefore compared with the standard immediately after the final dilution was made. Most of the urines examined were very concentrated, and 5 c.c. usually contained enough creatinine to give a reading on the colorimeter between 7 and 9, the standard being set at 8. If, however, the reading came beyond these limits the estimation was always repeated with a larger or smaller quantity of the urine. The usual 0·1N potassium bichromate solution was employed as a standard, and was carefully checked by a solution of pure creatinine picrate.

Of the other constituents the total sulphur was estimated by Benedict's method, the inorganic, ethereal and neutral sulphates by

Folin's methods, the phosphoric acid by titration with uranium acetate, and the chlorine by Volhard's method. The gravity was determined by Mohr's balance.

The full details of the analyses are given in the protocols at the end of the paper.

VOLUME, SPECIFIC GRAVITY AND TOTAL NITROGEN

Determinations of these have been made on the twenty-four hours' urine at different times, each experiment lasting from four to ten days so as to obtain a fair average. Most of these were done in the hot season of the year (November to April) when the atmospheric humidity is high, but in two cases comparisons were made in the cooler season (May to October).

The full details are given in the protocols, whilst the averages for each set of experiments are collected in Table 1, the number in

TABLE 1.—Volume, Specific Gravity and Total Nitrogen of the Urine

No.	Subject	Age	Weight kilos	Protocol	Season	24 Hours Urine			
						Vol. c.c.s.	Spec. grav.	Nitrogen in Grams	
								Total	Per kilo of body weight
1	A	32	66·8	1	hot	986	1,023	11·69	0·175
2	A	33	66·8	2	hot	772	1,027	11·58	0·173
3	A	33	66·8	3	hot	1,070	1,024	14·33	0·214
4	B	25	60·6	5	hot	922	1,027	12·41	0·205
5	D	30	63·1	8	hot	782	1,026	10·83	0·172
6	D	30	62·8	7	cool	1,437	1,017	12·11	0·193
7	E	36	48·2	11	hot	621	1,023	8·83	0·183
8	E	35	48·4	9	cool	1,037	1,021	11·69	[illegible]
9	E	36	48·2	10	cool	1,372	1,012	[illegible]	[illegible]
10	C	27	62·2	6	cool	1,367	1,014	[illegible]	[illegible]
Average for both seasons, 5 persons					—	1,070	1,021	[illegible]	[illegible]
Average for hot season, 4 persons					—	[illegible]	1,025	[illegible]	[illegible]
Eijkman's average for 19 Europeans in Java						[illegible]	[illegible]	[illegible]	[illegible]
Pflüger and Bohland for Europeans								[illegible]	[illegible]
Bleibtreu and Bohland for Europeans								[illegible]	[illegible]

the fifth column referring to the protocol containing the full data. For comparison are also given the figures obtained by Eijkman for Europeans living in Java, as well as those for Europe found by Pflüger and Bohland and Bleibtreu and Bohland. The volume of urine varies from day to day, but the average figures show that during the hot humid weather, when any exertion is accompanied by profuse sweating, the urines are comparatively small in volume and of high gravity. The volume of liquid taken in was generally between 3 and 4 litres a day.

Nos. 5, 6, 7, 8 and 9 show the effect of the season on the excretions of the same individuals. The total nitrogen also shows daily variations, but the averages, 8·8 to 14·3 grams, are somewhat lower than that given in the physiological text-books as the average for Europe, 14 to 18 grams. When the nitrogen is considered in relation to the body weight it does not differ appreciably from that found in Europe. In the cases examined the daily excretion of nitrogen was greater in the cool season than in the hot. Part of this difference is no doubt due to the nitrogen lost in the sweat during the hot weather. Eijkman (1893) found that as much as 0·76 to 1·36 grams of nitrogen per day were excreted cutaneously by Malays, whilst Benedict (1906) outside the tropics, found that during rest the nitrogen lost in this way was about 0·071 grams per day, but during severe muscular labour as much as 0·13 to 0·22 grams per hour.

During the hot part of the year a nitrogen-balance experiment was carried out on subject A. The numbers, Table 2, have not

Table 2.—Nitrogen balance on fixed diet.

Date	Nitrogen in food	Nitrogen Excreted			Balance
		Urine	Faeces	Total	
4·3·14	26·58	17·01	2·99	20·00	+ 6·58
5·3·14	26·58	18·87	1·50	20·37	+ 6·21
6·3·14	26·58	19·24	3·52	22·76	+ 3·82
7·3·14	26·58	20·32	1·82	22·14	+ 4·44

been included in the general averages, since the diet, which was restricted to milk and bread and butter, was of much higher nitrogen content than the usual diet. The subject increased in weight by 1·3 kilos during the four days, and complained of feeling uncomfortably full after the meals. The numbers show a considerable nitrogen retention amounting to 21 grams, a small part of which may be accounted for by the cutaneous excretion.

UREA

The excretion of urea varies with the total nitrogen.

The average daily outputs in the different subjects varied from 26·98 grams in A to 14·79 grams in E, or 87·9 % to 78·4 % of the total nitrogen excreted respectively. The quantity of urea generally quoted as the average for Europeans on a mixed diet is 30 grams per diem; the quantities found were always less than this amount, but when considered in relation to the total nitrogen appear quite normal.

AMMONIA

The ammonia present in the urines was quite normal in amount, the averages varying from 0·50 grams to 0·64 grams, or 4·8 % and 3·6 % of the total nitrogen respectively. The average output for all four subjects being 0·57 grams.

CREATININE AND CREATINE

Creatine was only present in any of the urines on one occasion, and then only in a very small amount (0·12 grams nitrogen).

A number of determinations of the creatinine have been made both in the hot weather and in the cooler season. Table 3 gives the averages over the whole periods, given in detail in the protocols, each figure representing the average output per day for a period of several days. These averages vary between 0·47 grams and 0·71 grams of nitrogen per day, representing between 3·2 and 6·1 % of the total nitrogen. In normal individuals in temperate climates the daily excretion is, according to Folin (1905) from 3·5 to 4·5 %, whilst van Hoogenhuyze and Verploegh (1905) found values of 4 to 6%. Leathes observed that although during fever there was an increase in the actual amount of creatinine excreted there was at the same time increased nitrogen, so that the percentage of the nitrogen which appeared as creatinine was actually diminished.

If the creatinine in the urine be considered in relation to the body weight, column 8, it is seen that the quantity excreted varies in the different individuals from 8·52 mgrms. to 10·62 mgrms. per kilo of body weight, values which agree with the figures given by Folin, namely, 7 to 11 mgms. per kilo of body weight.

TABLE 3.—The Excretion of Creatinine

No.	Subject	Season	Protocol	Total N. grms.	Creatinine Nitrogen		
					grms.	per cent. of total N.	per kilo of body wt. mgrms.
1	A	hot	1	11·60	0·61	5·4	9·13
2	A	hot	2	11·58	0·71	6·1	10·62
3	A	hot	3	14·33	0·62	4·4	9·28
4*	A	hot	4	18·86	0·63	3·2	9·43
5	B	hot	5	12·41	0·64	5·1	10·56
6	D	hot	8	12·83	0·57	5·2	9·03
7	D	cool	7	12·11	0·58	4·8	9·23
8	E	hot	11	8·83	0·49	5·6	10·16
9	E	cool	9	11·69	0·47	4·1	9·71
10	C	cool	6	11·02	0·53	4·9	8·52

* No. 4 on special milk and bread diet = 26·6 grms. N.

As in all these experiments, with the exception of No. 4, the diets contained creatine, the quantities of creatinine excreted are probably slightly higher than that which represents tissue metabolism alone.

The figures, therefore, so far as they go, supply no evidence of a greater creatinine output in a tropical climate, nor do they show any marked seasonal variation.

URIC ACID

The average quantity of uric acid varied from 0·42 to 0·56 grams per day, which is quite a normal figure for a mixed diet.

PURIN BASES

The considerable variations observed in the daily excretion of the purin bases are to be attributed to the tea and coffee of a mixed diet, since the greater part of these substances in the urine arise from this source. This is confirmed by the fact that with A on mixed diet (protocol III) these substances varied from 58 mgrms. to 92 mgrms. per day, whilst on a bread and milk diet (protocol IV, the quantity was much less and more constant, and varied during the next three days only from 21 to 28 mgrms.

PHOSPHORIC ACID

The phosphoric acid varied very considerably, the average on mixed diet being between 1·56 and 2·61 grams per day. The nitrogen to P_2O_5 ratio usually accepted for male Europeans is 5 or 6 : 1; in every case but one the average ratio found lay between 5·5 and 5·9, the exception showed a ratio of 7·1.

CHLORIDES

The quantity of chlorides excreted was too variable in amount to allow of any conclusions.

SULPHUR

The total sulphur when compared with the nitrogen gave ratios N : S of 14 to 15, this is somewhat higher than the average given in the text-books on Physiology, viz., 12·75, but Cathcart and Green (1913) during a number of determinations of this ratio, when different proteins were superimposed on a fixed diet, found in some cases numbers as high as this.

The quantities of neutral sulphur excreted were rather high, representing on a full protein diet from 11·8 to 20·8 % of the total sulphur, and averaging from 0·250 grams to 0·455 grams per day as SO_3. The average quantity on a full diet is, according to Folin, about 0·25 grms. per day, or about 5 % of the total sulphur. On a low protein diet he found no lessening in the amount excreted, the quantity then representing 25 % of the total sulphur. The inorganic sulphates and the ethereal sulphates were quite normal in amount.

CONCLUSION

The number of subjects upon which the experiments were carried out is, of course, too few to draw any definite conclusions, but as far as they go they exhibit no marked variations from the averages obtained in temperate climates. In every case the neutral sulphur was high, but whether this is due to an increased tissue metabolism, or not, only further experiment will show.

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PROTOCOLS

I

SUBJECT A.—33 years; weight = 66·8 kilos; four years in Tropics

Date 1913	Volume c.c.s.	Specific gravity	Total nitrogen, grms.	Creatinine		
				grms.	As nitrogen grms.	per cent. of total nitrogen
Mar. 19 ...	1,487	1,015	14·20	1·65	0·61	4·32
„ 20 ...	1,425	1,013	10·25	1·47	0·55	5·32
„ 21 ...	1,030	1,028	15·31	1·51	0·56	3·67
„ 22 ...	775	1,027	9·17	1·59	0·59	6·44
„ 23 ...	690	1,026	9·52	1·55	0·58	6·05
„ 24 ...	875	1,025	12·07	1·56	0·58	4·80
„ 25 ...	745	1,026	9·61	1·89	0·70	7·31
„ 26 ...	880	1,027	12·12	1·99	0·74	6·10
„ 27 ...	970	1,022	12·93	1·52	0·57	4·37
Averages ...	986	1,023	11·69	1·64	0·61	5·38

II

Date 1913	Volume c.c.s.	Specific gravity	Total nitrogen grms.	Creatinine		
				grms.	As nitrogen grms.	per cent. of total nitrogen
Dec. 16 ...	730	1,029	12·43	2·24	0·83	6·70
„ 17 ...	675	1,028	11·31	1·93	0·72	6·34
„ 18 ...	895	1,024	12·38	2·00	0·74	[illegible]
„ 19 ...	755	1,027	9·60	1·67	0·62	[illegible]
„ 20 ...	875	1,026	12·04	1·92	[illegible]	[illegible]
„ 21 ...	820	1,025	11·37	2·02	[illegible]	[illegible]
„ 22 ...	720	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]
„ 23 ...	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]
Averages ...	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]

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" 25 ...	745	1,026	9·61	1·89	0·70	7·31
" 26 ...	880	1,027	12·12	1·99	0·74	6·10
" 27 ...	970	1,022	12·93	1·52	0·57	4·37
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" 19 ...	755	1,027	9·60	1·67	0·62	6·46
" 20 ...	875	1,026	12·04	1·92	0·71	5·92
" 21 ...	820	1,028	11·37	2·02	0·75	6·60
" 22 ...	720	1,030	11·26	1·78	0·66	5·86
" 23 ...	705	1,028	12·24	1·73	0·64	5·25
Averages ...	772	1,027·5	11·58	1·91	0·71	6 14

III

A.—Mixed Diet

Date	Volume c.c.	Gravity	P_2O_5	NaCl	Total N.	Urea	Ammonia	Creatinine	Uric acid	Purin bases mgms. N.	Sulphur as SO_3 Total S.	Inorganic sulphates	Ethereal sulphates	Neutral S.	Ratio N. : S.	Ratio N. : P_2O_5
12.2.14	1,100	1,022	2·00	10·85	12·74	24·67	0·51	1·74	0·44	58	2·271	1·661	0·194	0·416	14·0	6·4
13.2.14	1,105	1,022	2·41	13·47	12·82	24·41	0·53	1·82	0·44	73	2·227	1·713	0·186	0·328	14·4	5·3
14.2.14	1,045	1,024	2·66	12·03	14·59	26·29	0·62	1·67	0·55	81	2·491	1·886	0·178	0·427	14·6	5·9
15.2.14	930	1,028	2·90	9·60	12·75	23·04	0·62	1·54	0·39	64	2·688	2·104	0·142	0·442	11·8	4·4
16.2.14	1,425	1,020	3·03	10·90	17·28	33·40	0·91	1·72	0·49	62	3·159	2·182	0·294	0·683	13·7	5·7
17.2.14	1,000	1,026	3·05	8·50	15·69	29·43	0·68	1·67	0·38	92	2·692	2·013	0·175	0·504	14·6	5·1
18.2.14	885	1,027	2·23	7·42	14·47	27·61	0·57	1·58	0·41	59	2·352	1·767	0·203	0·382	15·0	6·5
Averages ...	1,070	1,024	2·61	10·38	14·33	26·98	0·63	1·68	0·44	70	2·554	1·904	0·196	0·455	14·0	5·5

Date	Percentage of total N. excreted as Urea	Ammonia	Creatinine	Uric acid	Purin bases	Rest	Percentage of total S. Inorganic sulphates	Ethereal sulphates	Neutral S.
12.2.14	90·3	3·3	5·1	1·2	0·5	[illegible]	73·14	8·54	18·32
13.2.14	88·8	3·4	5·3	1·2	0·6	0·7	76·92	8·32	14·72
14.2.14	84·1	3·5	4·2	1·2	0·6	5·6	75·71	7·15	17·14
15.2.14	84·3	4·0	4·5	1·0	0·5	5·7	78·27	5·28	16·44
16.2.14	90·2	4·3	3·7	0·9	0·4	0·5	69·07	9·31	21·62
17.2.14	87·5	3·6	3·9	0·8	0·9	3·8	74·77	6·50	18·72
18.2.14	88·9	3·2	4·1	1·0	0·4	2·4	75·13	8·63	16·24
Averages	87·9	3·6	4·4	1·0	0·5	2·7	76·14	7·68	17·60

IV

A.—Bread and Milk Diet

Date	Volume ccs.	Gravity	P_2O_5	NaCl	Total N	Urea	Ammonia	Creatinine	Uric acid	Purin bases mgms. N.	Sulphur as SO_3 Total S.	Sulphur as SO_3 Inorganic sulphates	Sulphur as SO_3 Ethereal sulphates	Sulphur as SO_3 Neutral S.	Ratio N. : S.	Ratio N. : P_2O_5
4.3.14	1,015	1,024	2·47	8·70	17·01	33·05	0·70	1·75	0·47	56	3·283	2·667	0·201	0·415	12·9	6·9
5.3.14	1,200	1,023	3·22	13·19	18·87	36·61	0·76	1·67	0·43	28	3·165	2·694	0·120	0·351	14·9	5·9
6.3.14	1,165	1,023	3·48	13·14	19·24	36·57	0·73	1·73	0·49	21	3·276	2·786	0·111	0·379	14·7	5·5
7.3.14	1,152	1,023	3·69	12·99	20·32	37·90	0·78	1·71	0·46	23	3·315	2·842	0·107	0·366	15·3	5·5
Averages ...	1,133	1,023	3·28	12·00	18·86	36·03	0·74	1·71	0·46	32	3·260	2·747	0·135	0·378	14·4	5·9

Date	Percentage of total N. as Urea	Ammonia	Creatinine	Uric acid	Purin bases	Rest	Percentage of total S. Inorganic	Ethereal	Neutral
4.3.14	87·6	3·0	3·3	0·9	0·4	4·8	81·24	6·12	12·64
5.3.14	90·5	3·3	3·2	1·0	0·1	1·9	85·12	3·79	11·09
6.3.14	89·1	3·1	3·3	0·8	0·1	3·7	85·04	3·39	11·57
7.3.14	87·1	3·1	3·1	0·8	0·1	5·8	85·73	3·23	11·04
Averages	88·7	3·1	3·2	0·9	0·2	4·0	84·28	4·13	11·58

V

Subject B.—25 years; weight = 60·6 kilos.; 4 years in Tropics; mixed diet.

Date	Volume ccs.	Gravity	P_2O_5	NaCl	Total N	Urea	Ammonia	Creatinine	Uric acid	Purin bases mgms. N.	Sulphur as SO_3: Total S.	Inorganic sulphates	Ethereal sulphates	Neutral S.	Ratio N. : S.	Ratio N. : P_2O_5
3.4.14	980	1,028	2·00	13·63	13·21	22·78	0·72	1·80	0·61	79	2·371	1·883	0·179	0·309	14·3	6·6
4.4.14	950	1,027	1·67	13·81	12·35	22·16	0·53	1·67	0·55	45	1·942	1·457	0·175	0·310	15·9	7·4
5.4.14	825	1,026	1·65	10·84	11·60	19·99	0·59	1·68	0·50	69	2·218	1·668	0·199	0·351	13·1	7·0
6.4.14	932	1,027	1·72	12·76	12·48	21·92	0·62	1·72	0·57	72	2·178	1·701	0·182	0·294	14·3	7·3
Averages ...	922	1,027	1·76	12·76	12·41	21·71	0·61	1·72	0·56	64	2·177	1·677	0·184	0·316	14·4	7·1

Date	Percentage of total N. as: Urea	Ammonia	Creatinine	Uric acid	Purin bases	Rest	Percentage of total S. as: Inorganic	Ethereal	Neutral
3.4.14	80·5	4·5	5·1	1·5	0·6	7·8	79·42	7·55	13·03
4.4.14	83·7	3·6	5·0	1·5	0·4	5·8	75·03	9·01	15·96
5.4.14	80·4	4·2	5·3	1·4	0·6	8·1	75·20	8·97	15·82
6.4.14	81·3	4·1	5·1	1·5	0·6	7·4	78·13	8·36	13·51
Averages	81·5	4·1	5·1	1·5	0·5	7·3	76·94	8·47	14·58

VI

Subject C.—27 years; weight = 62·2 kilos; 2½ years in Tropics.

Date 1913	Volume ccs.	Specific gravity	Total nitrogen grms.	Creatinine		
				Grms.	As nitrogen	Percentage of Total N.
July 30 ...	1,540	1,011	10 86	1·44	0·53	4·94
„ 31 ...	1,040	1,020	13·31	1 65	0·61	4 61
Aug. 1 ...	1,170	1,014	10·37	1·40	0·52	5·04
„ 2 ...	1,480	1,014	11·31	1·45	0·54	4 76
„ 3 ...	1,100	1,017	10·00	1·47	0·55	5·48
„ 4 ...	1,255	1,015	10·84	1·46	0·54	5·02
„ 5 ...	1,430	1,014	10·25	1·44	0·53	5·22
„ 6 ...	1,625	1,010	10·42	1·30	0·48	4·65
„ 7 ...	1,665	1,011	11·87	1·36	0·50	4·27
Averages ...	1,367	1,014	11·02	1·44	0·53	4·89

VII

Subject D.—30 years; weight = 62·8 kilos; 1-1½ years in Tropics.

Date, 1913	Volume ccs.	Specific gravity	Total nitrogen grms.	Creatinine		
				Grms.	As nitrogen grms.	percentage of Total N.
July 30 ...	2,340	1,011	13·72	1·80	0·67	4·87
„ 31 ...	970	1,024	12·15	1·40	0·52	4·27
Aug. 1 ...	1,540	1,018	12·28	1·66	0·62	5·02
„ 2 ...	1,730	1,012	12·26	1·85	0·69	5·60
„ 3 ...	970	1,024	11·85	1·48	0·55	4·65
„ 4 ...	1,190	1,019	13·86	1·59	0·59	4·42
„ 5 ...	1,310	1,015	12·10	1·45	0·54	4·45
„ 6 ...	1,430	1,015	11·51	1·53	0·57	4·95
„ 7 ...	1,950	1,012	9·71	1·29	0·48	4·92
„ 8 ...	940	1,020	11·62	1·50	0·56	4·79
Averages ...	1,437	1,017	12·11	1·55	0·58	4·79

VIII

D.—Mixed Diet; 63·1 kilos

Date	Volume ccs.	Gravity	P_2O_5	NaCl.	Total N.	Urea	Ammonia	Creatinine	Uric acid	Purin bases mgms. N.	Sulphur as SO_3 Total S.	Inorganic sulphates	Ethereal sulphates	Neutral S.	Ratio N. : S.	Ratio N. P_2O_5
6.4.14	890	1,025	1·68	11·68	10·86	18·79	0·55	1·54	0·37	103	2·082	1·575	0·088	0·419	13·0	6·5
7.4.14	710	1,026	2·14	7·05	11·46	20·79	0·55	1·51	0·47	77	1·962	1·412	0·156	0·394	14·6	5·4
8.4.14	790	1,028	2·06	6·84	11·00	19·72	0·56	1·67	0·47	78	2·110	1·539	0·149	0·422	13·7	5·3
9.4.14	470	1,028	1·47	3·88	8·78	15·19	0·45	1·26	0·34	28	1·375	0·928	0·096	0·351	15·8	6·0
10.4.14	832	1,025	2·03	6·98	12·66	22·95	0·56	1·74	0·51	157	2·086	1·440	0·196	0·450	14·5	6·2
11.4.14	790	1,027	1·93	8·25	10·30	17·98	0·45	1·47	0·37	118	1·754	1·270	0·170	0·308	14·7	5·3
12.4.14	995	1,020	2·03	6·98	10·74	19·43	0·41	1·54	0·45	82	1·506	0·995	0·200	0·311	17·8	5·3
Averages ...	782	1,025	1·96	7·38	10·83	19·26	0·50	1·53	0·42	92	1·836	1·308	0·151	0·379	14·9	5·7

Date	Percentage of Total N. as Urea	Ammonia	Creatinine	Uric acid	Purin bases	Rest	Percentage of Total S. as Inorganic	Ethereal	Neutral
6.4.14	80·8	4·1	5·2	1·1	0·9	7·9	75·65	4·23	20·12
7.4.14	84·6	3·9	4·9	1·4	0·7	4·5	71·97	7·95	20·08
8.4.14	83·6	4·2	5·6	1·4	0·7	4·5	72·94	7·06	20·00
9.4.14	80·8	4·2	5·3	1·2	0·3	8·2	67·49	6·98	25·58
10.4.14	84·6	3·6	5·1	1·3	1·2	4·2	69·03	9·40	21·57
11.4.14	81·4	3·6	5·3	1·2	1·2	7·3	72·40	10·03	17·56
12.4.14	84·4	3·2	5·3	1·4	0·8	4·9	66·07	13·28	20·65
Averages	82·9	3·7	5·2	1·3	0·8	6·3	69·36	8·42	20·80

IX

SUBJECT E.—36 years; 48·4 kilos; 1 to 1½ years in Tropics

Date, 1913	Volume ccs.	Specific gravity	Total nitrogen grms.	Creatinine		
				Grms.	As nitrogen grms.	Percentage of Total N.
July 6 ...	790	1,022	9·04	1·28	0·48	5·3
„ 7 ...	915	1,023	10·47	1·32	0·49	4·7
„ 8 ...	970	1,022	11·79	1·28	0·48	3·9
„ 9 ...	1,185	1,016	10·19	1·22	0·45	4·5
„ 10 ...	1,118	1,018	11·36	1·22	0·45	4·0
„ 11 ...	1,510	1,016	11·50	1·34	0·50	4·3
„ 12 ...	895	1,024	12·60	1·28	0·48	3·8
„ 13 ...	850	1,026	13·08	1·20	0·45	3·4
„ 14 ...	1,370	1,015	14·30	1·21	0·45	3·1
„ 15 ...	770	1,026	12·54	1·31	0·49	3·9
Averages ...	1,037	1,021	11·69	1·27	0·47	4·1

X

E. Weight = 48·2 kilos.

Date, 1914	Volume ccs.	Specific gravity	Total nitrogen grms.
June 25	1,540	1,011	9·97
„ 26	1,150	1,013	10·86
„ 27	1,460	1,012	10·77
„ 28	1,340	1,013	10·50
Averages ...	1,372	1,012	10·52

XI

E.—Mixed Diet

Date	Volume ccs.	Gravity	P_2O_5	NaCl	Total N	Urea	Ammonia	Creatinine	Uric acid	Purin bases mgms. N.	Sulphur as SO_3: Total S.	Inorganic sulphates	Ethereal sulphates	Neutral S.	Ratio N : S	Ratio N : P_2O_5
18.3.14	540	1,024	1·63	3·80	8·04	13·62	0·47	1·38	0·53	67	1·293	0·935	0·109	0·249	15·5	4·9
19.3.14	555	1,024	1·69	3·81	8·88	14·55	0·36	1·32	0·52	67	1·447	1·105	0·120	0·222	15·3	5·2
20.3.14	505	1,025	1·61	3·92	9·12	14·98	0·57	1·32	0·50	56	1·441	1·209	0·078	0·154	15·8	5·7
21.3.14	600	1,024	1·61	5·84	8·74	14·19	0·49	1·29	0·45	60	1·396	1·014	0·120	0·262	15·7	5·4
22.3.14	673	1,023	1·49	5·70	8·18	13·28	0·49	1·26	0·47	95	1·581	1·108	0·199	0·274	12·9	5·5
23.3.14	804	1,020	1·45	5·40	9·46	16·07	0·64	1·39	0·52	76	1·707	1·359	0·135	0·213	13·8	6·5
24.3.14	640	1,024	1·44	6·52	9·43	16·85	0·57	1·27	0·39	73	1·496	0·960	0·157	0·379	15·8	6·5
Averages ...	621	1,023	1·56	5·00	8·83	14·79	0·51	1·32	0·48	71	1·480	1·099	0·131	0·250	15·0	5·7

Date	Percentage of total N. as: Urea	Ammonia	Creatinine	Uric acid	Purin bases	Rest	Percentage of total S. as: Inorganic	Ethereal	Neutral
18.3.14	79·1	4·8	6·3	2·2	0·8	6·8	72·31	8·43	19·26
19.3.14	77·4	3·4	5·6	1·9	0·8	10·9	76·36	8·29	15·34
20.3.14	76·6	5·1	5·4	1·8	0·6	10·5	83·90	5·41	10·69
21.3.14	77·5	4·6	5·5	1·7	0·7	10·0	72·63	8·60	18·77
22.3.14	75·8	4·9	5·7	1·9	1·2	10·5	70·08	12·59	17·33
23.3.14	79·3	5·6	5·5	1·8	0·8	7·0	79·61	7·91	12·48
24.3.14	83·3	5·0	5·0	1·4	0·8	4·5	64·17	10·49	25·33
Averages	78·4	4·8	5·6	1·8	0·8	8·6	74·15	8·82	17·03

THE UNIVERSITY OF LIVERPOOL

ANNALS
OF
TROPICAL MEDICINE AND PARASITOLOGY

ISSUED BY THE

LIVERPOOL SCHOOL OF TROPICAL MEDICINE

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VOLUME IX
(March 18, 1915, to December 30, 1915)

With Frontispiece, thirty-nine plates, twenty-five figures in text, twenty-four charts, and three maps

LIVERPOOL
AT THE UNIVERSITY PRESS, 57 ASHTON STREET