LXXX. DAY AND NIGHT URINE DURING COMPLETE REST, LABORATORY ROUTINE, LIGHT MUSCULAR WORK AND OXYGEN ADMINISTRATION.

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INTRODUCTION.

By employing the same subject under varying daily routines it was thought that some information might be obtained regarding the problems of nitrogen metabolism and urinary excretion, if close attention were directed to the composition of the day and night urine. The present results were obtained during three 5-day periods: (i) complete rest in bed, (ii) 6½ hours' ordinary laboratory routine, (iii) 1½ hours' ordinary laboratory routine plus 5 hours' work—13,500 kgm. per hr.—on Schuster's [1921] modification of Martin's bicycle ergometer. For brevity these periods will be called "rest routine," "ordinary routine," and "ergometer routine" respectively. During the "ergometer routine" the subject may be considered to have carried out half-a-day's work of a labourer.

The subject, 28 years of age, 161.2 cm. in height, and 52.4 kgm. in weight, was a skilled laboratory assistant, and accustomed to this type of research. During six months of observation his total nitrogen excretion averaged 9 g. His usual diet was taken, but was controlled mainly to exclude articles which are known to influence greatly the composition of the urine. The average daily diet for each of the 5-day periods was similar in substance. Breakfast was taken about 7.30 a.m., dinner at 1 p.m., light tea at 4 p.m., and supper at 7.30 p.m.

Well-known standard methods were used for the analyses and the average results are given in the appended table.

Composition of average day and night urines under "rest routine," "ordinary routine" and "ergometer routine."

The urine was collected in two samples, day urine between 7 a.m.—5 p.m., night urine between 5 p.m.—7 a.m. in most cases. On a few occasions the day urine included the hours 7 a.m.—10 p.m. and the night urine 10 p.m.—7 a.m. with no important effect on the results. We can find very few experiments

of a like nature in the literature. Osterberg and Wolf [1907] carried out a few days' observations using two different diets, and collecting the urine between 11 a.m.–11 p.m. for the day and 11 p.m.–11 a.m. for the night, allowing 3 hours for "lag in excretion," so that they considered the night urine belonged to 8 p.m.–8 a.m. The largest meal in their case was taken at 7 p.m. In our case the largest meal was taken at 1 p.m. In only a few points can their results be compared with ours owing to the different conditions of experiment.

Water and chloride. Much less water and much less chloride were excreted during the night than during the day. Both were reduced in proportion.

Total nitrogen. Under our conditions of experiment and arrangements for meals, we always noted during all routines a much higher excretion of nitrogen per hour during the day than during the night. Lusk [1917, p. 110] records a similar result for a fasting subject. Osterberg and Wolf [1907] found no regularity as regards the day and night nitrogen under their conditions.

Average hourly day and night results.

	"Rest routine"		"Ordinary routine"		"Ergometer routine"	
	Day	Night	Day	Night	Day	Night
Amount cc.	67.2	31.3	61.2	27.0	58.5	27.6
Acidity %	20.6	70.2	44.8	64.6	50.0	64.0
Titrateable acidity (Folin), cc. N/10	5.4	18.2	10.4	16.8	11.6	15.4
Total acidity, cc. N/10	18.8	36.7	25.4	33.0	28.1	31.6
Total N g.	.386 (100)*	.296 (100)	.428 (100)	.332 (100)	.447 (100)	.357 (100)
Urea N g.	.319 (82.70)	.199 (67.20)	.346 (80.90)	.254 (76.60)	.369 (82.50)	.283 (79.30)
Ammonia N (A) g.	.014 (3.63)	.022 (7.43)	.015 (3.50)	.019 (5.72)	.017 (3.80)	.019 (5.32)
Ammonia N (B) g.	.019	.026	.020	.022	.023	.023
Amino-acid N g.	.005 (1.30)	.004 (1.35)	.005 (1.17)	.003 (0.90)	.006 (1.34)	.004 (1.12)
Creatinine N g.	.032 (8.29)	.029 (9.80)	.032 (7.48)	.031 (9.34)	.030 (6.71)	.028 (7.86)
Uric acid N g.	.008 (2.07)	.005 (1.69)	.007 (1.63)	.005 (1.51)	.007 (1.56)	.005 (1.40)
Undetermined N g.	.007 (2.01)	.035 (12.53)	.023 (5.32)	.018 (5.96)	.018 (4.09)	.018 (5.00)
Chloride (NaCl) g.	.596	.246	.417	.171	.531	.249
Phosphate (P ₂ O ₅) g.	.043	.080	.065	.080	.066	.075
Total S(SO ₃) g.	.066 (100)	.066 (100)	.078 (100)	.069 (100)	.073 (100)	.074 (100)
Inorganic S(SO ₃) g.	.042 (63.6)	.048 (74.1)	.058 (75.3)	.058 (84.1)	.060 (82.2)	.059 (79.7)
Ethereal S(SO ₃) g.	.011 (18.2)	.006 (10.5)	.005 (6.4)	.006 (8.7)	.006 (8.2)	.006 (8.1)
Neutral S(SO ₃) g.	.011 (18.2)	.009 (15.4)	.014 (18.2)	.005 (7.2)	.007 (9.5)	.009 (12.1)
Lactic acid per 100 cc.	trace	trace	trace	trace	trace	trace
Calcium (CaO) g.	—	—	.015	.007	.014	.008
Magnesium (MgO) g.	—	—	.007	.006	.006	.007
Purine N g.	.0011	.0017	—	—	—	—

(A) Van Slyke's method.

(B) Malfatti's method.

Total acidity is ammonia (B) + titrateable acidity.

* Figures in brackets are percentages.

Nitrogen partition. The main difference between the nitrogen partition for the day and for the night under all routines was the greater excretion—both relative and absolute—of ammonia. Other slight differences for all routines were noted; creatinine was excreted in greater amount during the day than at

night; urea, uric acid and amino-acids were excreted in greater amount—usually absolutely and relatively—during the day, than at night. The undetermined nitrogen was excreted in much greater amount at night than during the day under the “rest routine”; under the “ordinary routine” and the “ergometer routine” it was more or less equally distributed, so that it was increased during the day by activity. Osterberg and Wolf [1907] found that it was increased during work. They also found that the ammonia was higher during sleep, and that uric acid was increased during the day. Leathes [1907] previously pointed out that uric acid excretion is most active in the early working hours and very much less at night. Our results, as already shown, support this statement. We also found that under all routines the urea was, relatively and absolutely, excreted in greater amount during the day.

Sulphur excretion. Total sulphur, total sulphates, and inorganic sulphates were excreted in larger quantity per hour per g. nitrogen at night than during the day, because whilst the total nitrogen was decreased at night, the sulphur and sulphates were evenly distributed between the day and night under all routines. This appears to differ from the general idea recorded by Lusk [1917, p. 169] that excretion of sulphur precedes the excretion of nitrogen when a protein containing known quantities of these elements is ingested; but the conditions of our experiments were not quite identical.

The excretion of inorganic sulphate in relatively greater amount at night under all routines indicates probably a special excretion of fixed acid.

For the whole 24 hours, inorganic sulphate was increased whilst ethereal sulphate was decreased by activity.

Phosphate excretion. Phosphates were excreted, under all routines, in greater quantity during the night.

Acidity. Lactic acid was present in traces both during the day and at night under all routines. The acidity per cent. [Leathes, 1919] and titratable acidity were distinctly higher during the night than during the day under all routines, the difference being most marked during the “rest routine,” so that activity out-of-bed hastened the excretion of acid.

Purine bodies were excreted in greater amount at night.

Calcium and Magnesium. Calcium was excreted in greater quantity during the day than during the night, whereas magnesium was evenly distributed. Calcium and magnesium obviously followed different courses.

DISCUSSION.

Phosphate tide. Broadhurst and Leathes [1920] and others have shown that there is a phosphate tide, the phosphate being excreted in larger amount during the evening than during the day. Leathes and Broadhurst have endeavoured to discover what is the cause of this tide, and consider that it is independent of the food and not wholly dependent on the acidity. They suggest that it may be due to some special tissue metabolism—nerve or muscle.

It is well known that the curve of phosphate excretion runs more or less parallel to the nitrogen curve but behind it; according to Cathcart [1921] the phosphate or the greater part of it is associated with special nucleoprotein of the food and tissues and may undergo a special form of catabolism. We have obtained some support to this opinion since we found that the purine bodies were excreted in greater amount at night than during the day; at the same time it should be mentioned that we found the uric acid to be excreted in greater amount during the day. We estimated the calcium and magnesium during the "ordinary routine" and "ergometer routine" with the idea that phosphate might show close connection with these substances. However, this was not found to be the case. We could find no connection with muscle or nerve activity in particular, as suggested by Leathes and Broadhurst, since the tide was best marked during the "rest routine."

We observed a close relationship between acidity, ammonia and phosphate excretion. Why is there an increase of acidity at night? It is not sufficient to state that the kidney is more active at night because respiration is depressed. The depression of respiration is no greater than the depression of activity, and the CO_2 excretion by the lungs possibly accounts for the contraction of heart and respiratory muscle which are working at a minimum. Again it will be remembered that the inorganic sulphate was excreted in relatively greater amount at night, indicating some special excretion of acid. It is reasonable to connect this with sleep. One of the well-known theories regarding sleep recorded by Howell [1911] offers an explanation. In this theory sleep is said to be due to accumulation of acid products in cells, these acids being excreted more slowly than they are formed during the day, and thus collecting in the cells with a resulting diminution of activity of the cells, particularly of the brain cortex. We suggest that the cells of the body may not excrete certain fixed acids into the blood until certain amounts are formed in each cell. When this is the case these acids are excreted into the blood and fatigue or sleep is produced. There is presumably a threshold value for excretion, by the cells, of these acids.

Alkaline tide. The so-called alkaline tide is considered here because some text-books state that the urine is more acid at night as there are alkaline tides during the day. We have made numerous observations on our subject during the past six months and find that without exception the urine was more acid just after a meal—probably due to removal of alkaline phosphate in saliva—and less acid about two or three hours after a meal—probably due to removal of HCl in gastric secretion—becoming, in some cases, actually alkaline as estimated by P_{H} . We find that the alkaline tide was often well marked after the mid-day meal, in more than half the cases being better marked than the tide following breakfast. This is contrary to Leathes' [1919] statement that so-called alkaline tides do not exist except in the morning, and that they are not connected with digestion.

We do not consider that in our experiments the presence of alkaline tide

alone made the urine more alkaline during the day than at night. Two possible tides fell within the day urine and two within the night urine. In some experiments it was arranged that all four meals fell within the day's urine, which thus included all possible tides. This did not increase the acidity at night. One of us [Campbell, 1920] has shown that a tide may follow any meal.

Influence of administration of 35-40 per cent. oxygen on urinary excretion.

35-40 per cent. oxygen was administered for $37\frac{1}{2}$ hours spread out over 58 hours' time. We were led to try the effect on urinary excretion, by a case in which oxygen was given in Leonard Hill's [1921] tent to reduce oedema and improve chronic ulcers of the leg. Marked improvement was obtained in the condition of the leg and at the same time the nitrogen, acid and ammonia were doubled in the patient's urine. The cause of this was obscure. It was thought that the absorption of inflammatory products might explain it.

We failed to obtain any marked difference in the urinary composition of our normal subject, the results being much the same under oxygen administration as under ordinary conditions.

SUMMARY.

1. Total nitrogen was decreased at night under all routines specified. Ammonia was increased at night. Creatinine, urea, uric acid and amino-acids were excreted in greater amounts during the day than during the night.

2. Acidity of the urine was distinctly higher during the night under all routines. Activity out-of-bed hastened the excretion of acid.

3. The phosphate tide at night is considered to be due to the increased acidity of the urine. It did not appear to be connected with muscle or nerve metabolism in particular.

4. The sulphur was evenly distributed between day and night.

5. The increase of acidity at night is considered to be due to delayed excretion of certain fixed acids formed in the cells during the day.

6. Administration of 35-40 per cent. of oxygen did not affect the composition of the urine.

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