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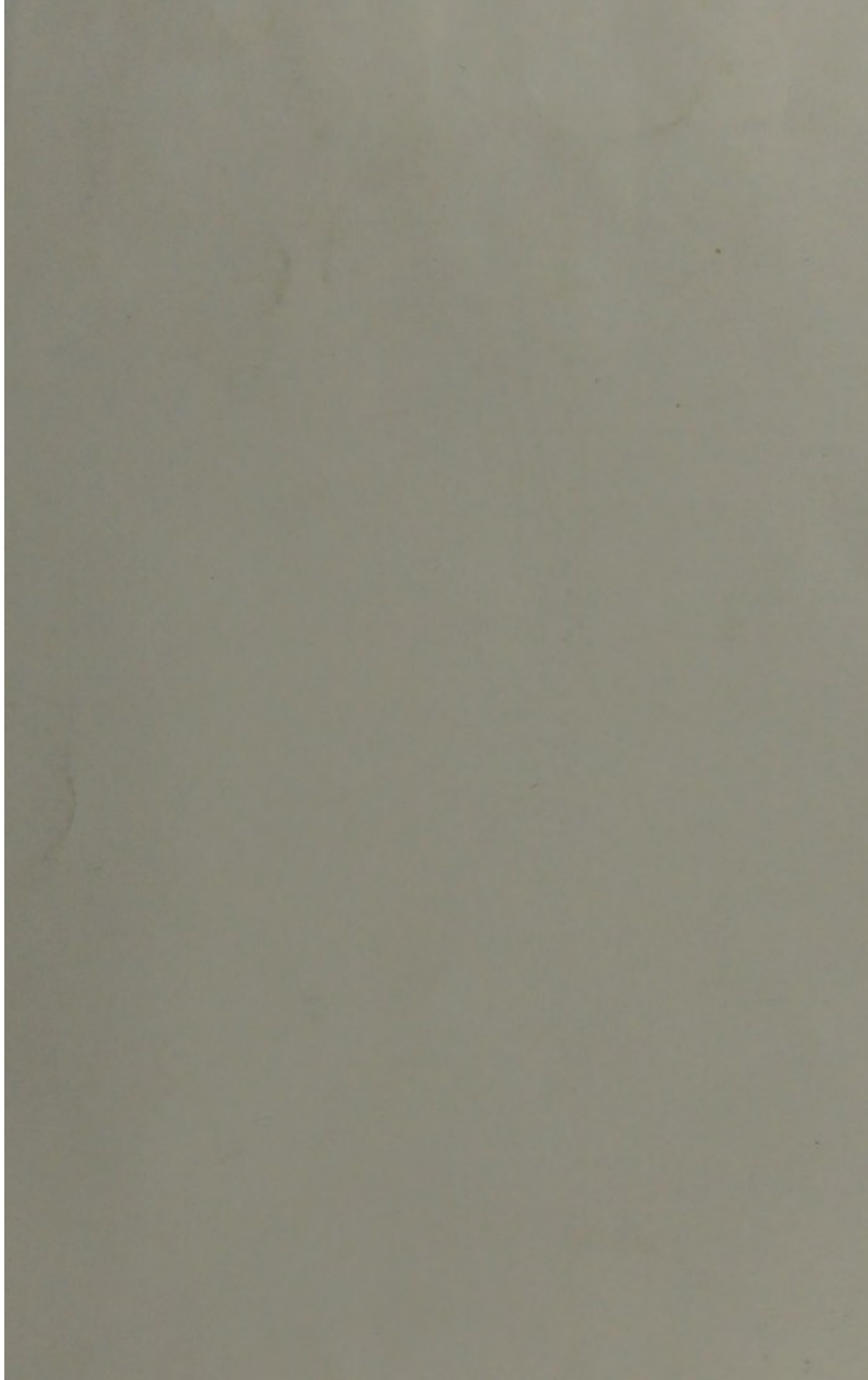
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Wellcome Collection  
183 Euston Road  
London NW1 2BE UK  
T +44 (0)20 7611 8722  
E [library@wellcomecollection.org](mailto:library@wellcomecollection.org)  
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XVI. — *A Contribution to Urology, embracing Observations on the Diurnal Variations in the Acidity of the Urine, chiefly in relation to Food.*

BY WILLIAM ROBERTS, B.A., M.D.,  
*Physician to the Manchester Royal Infirmary.*

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Read May 3rd, 1859.

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It has been the universal belief, until recently, that the reaction of the human urine was, in health, invariably acid; and that a neutral or alkaline condition of it was either a sign of disease, or the consequence of partaking of alkaline substances, or of subacid fruits, the vegetable salts of which, being broken up in the blood, appeared in the urine as alkaline carbonates.

In 1845 Dr. Bence Jones\* called this belief in question, and announced that he found that the urine became not unfrequently alkaline a few hours after taking food.

Three years later Dr. Jones investigated the subject comprehensively; and the result of his inquiries were published in the *Philosophical Transactions* for 1849. He conducted the inquiry as follows:—The urine was passed immediately before breakfast (about nine), and the acidity per 1000 grains estimated by a test solution of carbonate of soda. After breakfast the urine was passed about every hour or hour-and-half, and the products separately examined by the test solution. This went on till dinner (about six p.m). After dinner the observations were less frequent and regular. Generally the first examination was

\* *Phil. Trans.* 1845, p. 349.



made about two hours after the meal, and the next about three hours later. The urine of sleep and of the following morning were also separately examined. As a rule, about twelve distinct observations were made in each period of twenty-four hours. The effect of ordinary mixed food, of purely animal and of purely vegetable diet, was investigated during separate days on which one or other class of diet was exclusively used. He sums up his results in the following propositions: —

I. "As regards the variations of the acidity of the urine for three days on mixed diet. The acidity soon after food was found to decrease and to attain its lowest limit from three to five hours after breakfast and dinner; sooner however after breakfast than after dinner. The acidity then gradually increased and attained its highest limit just before food. If no food was taken the acidity of the urine did not decrease, but remained nearly the same for twelve hours. It fell immediately after food was taken.

II. "When animal food only was taken, the diminution of the acidity after food was more marked and more lasting than when a mixed diet was taken; and the acidity before food rose rather higher with a mixed diet than it did with animal food.

III. "When vegetable food only was taken the contrast with animal food was very marked. The urine did not decrease in acidity to the same degree; though it became neutral it did not become highly alkaline. The increase in the acidity of the urine was by no means so marked as the decrease of the alkalescence. The acidity of the urine was rather higher with the vegetable food than it was with animal food.

IV. "The result of these experiments is, that the acidity of the urine is always changing, and that the changes depend on the state of the stomach. When much acid is in the stomach the acidity is then diminished. As the acid



returns from the stomach the acidity of the urine increases, and generally reaches its highest limit before food is again taken."\*

These views have not obtained universal assent. It has been objected to them that they are based on observations on a single individual,† and cannot therefore be safely applied generally. And not only have no confirmatory facts been advanced, but subsequent observations have tended to re-establish the old opinion, that a neutral or alkaline state of the urine is an abnormal one. Dr. Beneke‡ examined his own urine on twenty-three days, and failed to detect any depression of the acidity as a result of taking food. In addition, he made not less than a hundred day-observations on different sick and healthy persons with this result — that, although the urine did occasionally show a depressed acidity and even an alkaline state after a meal, and especially after breakfast, yet this was very far from being constantly the case.

Dr. Julius Vogel§ rejects Dr. Jones's experiments on

\* *Phil. Trans.*, vol. lvi. p. 244.

† Although the experiments detailed in Dr. Jones's Paper were performed on a single individual, additional evidence of the effect of food on the reaction of the urine was advanced by him in the *Philosophical Transactions* for 1845, p. 345. He there says: "Dr. Andrews of Belfast stated to me, that having observed a case otherwise in perfect health, in which the urine was almost invariably alkaline about two hours after breakfast, so much so as frequently to be loaded with a deposition of phosphates whilst still in the bladder, he was led to observe the urine of about fifteen students in good health immediately after it was voided about noon. He found it to be alkaline in about two-thirds of the cases." "At the present time I know five physicians in whom the above phenomena at this period of the day are more or less frequently visible in a greater or lesser degree, and in London this alkalescence will be found in those who are considered generally healthy much oftener than is imagined."

‡ *Archiv des Vereins für gem. Arb. zur Förd. der Wissensch. Heilkunde*, vol. i. p. 438.

§ Neubauer und Vogel, *Anleitung zur Analyse des Harns*. 2nd edition, p. 175.



the ground that all his determinations were reckoned for 1000 parts instead of per hour. This objection would have had weight if the density of each specimen had not been recorded. Great dilution of the urine from abundant potation would no doubt reduce the *degree* of acidity per 1000 parts, even when the quantity of acid discharged per hour remained constant; but this source of fallacy was guarded against in the observations of Dr. Jones by taking the density of the secretion — this being a sufficient measure of its concentration. Dr. Vogel goes on to say: “Researches undertaken partly by myself, and partly by others under my direction, showed uniformly that the greatest quantity of acid secreted per hour by the kidneys occurred during the night, the least in the forenoon, while a medium quantity was discharged in the afternoon after the principal meal. These results therefore are unfavourable to the conclusions of Dr. Bence Jones, but do not tell conclusively against them, inasmuch as other circumstances may have had an influence on the amount of acidity.”

Dr. Sellers, in the *Edinburgh Medical Journal* for January 1859, states that in a good many trials he has not been able to satisfy himself “that the rule, as laid down by Dr. B. Jones, is generally applicable in Edinburgh; certainly not to the extent that the urine loses entirely its acid character, or that it becomes alkaline.” Nevertheless it has seemed to him “that the variations in the degree of its acidity are in some measure governed by the existing states of the stomach.”

Dr. Delavaud (*Gaz. Médicale*, 1851, No. 44) found the urine becoming neutral or alkaline after breakfast, but not after dinner.

Seeing this discrepancy in the results obtained by different observers, it seemed not undesirable to seek additional and exact information on the effect of food on the reaction



of the urine, and to find out some means, if it were possible, of reconciling the conflicting facts. The following experiments were undertaken with that purpose; and in a subsequent portion of the Paper some considerations are advanced which go far to account for this want of agreement.

All the experiments herein detailed concerned a single individual. He was a healthy man, twenty-eight years of age, taking moderate exercise, living in most favourable hygienic conditions, and weighing 144 lbs.

In order to ascertain the exact amount of change undergone by the urine after food, it was thought essential to collect the secretion at each hourly period succeeding a meal, and by measuring its quantity and saturating power to obtain data from which the precise amount of free acid or free alkali separated per hour by the kidneys could be estimated. At periods more remote from meal-times the urine was usually collected every two hours. As compared with Dr. Jones's method of merely ascertaining the degree of acidity or alkaliescence per 1000 grains, it had this important advantage, that it eliminated the inaccuracies consequent on the great inequality of concentration to which the urine is subject from food, drink, exercise and sleep, whereby its quantity and aqueousness rise or fall immensely, and with great suddenness.

The following particulars were taken of each urine, and arranged in a tabular form:—

I. *The Time of Day during which it was secreted.*

II. *The Quantity.* This was estimated in a glass vessel graduated on the scale of the 1000-grain measure. If the period of secretion exceeded or fell short of an hour by five, ten, or fifteen minutes, or if the period was two or more hours, as during sleep, the hourly rate of secretion was exactly calculated from the quantity and the interval. The results are arranged in the second columns of the



tables, and show in grain-measures the hourly rate of flow of the urine. From this volume-measure and the density the *weight* of urine per hour can be readily calculated.

III. *The Density.* A gravimeter of tried accuracy was usually employed. When the quantity was too scanty for the instrument, a 250-grain specific gravity bottle was substituted; and in one set of experiments of seven days (Table III.) the bottle was exclusively used.

IV. *The Solid Matters.* The amount of solid residue per 1000 grains was calculated according to Christison's formula.\* A second calculation from this and the hourly quantity gave, in grains, the solids separated per hour. These are arranged in the fourth columns. It is not pretended that these figures represent with accuracy the actual amounts, but as relative values they may be fairly assumed as near the truth. The results obtained are exceedingly uniform, considering the somewhat complicated, and avowedly uncertain, calculation on which they are based; and the remarkable conclusion to which they point is indicated with great distinctness.

V. *The Reaction.* The degree of acidity or alkalinity was ascertained by a test solution after the usual method in volumetrical analyses. For the former a solution of caustic soda was employed, and for the latter dilute sulphuric acid. The two solutions were made of equal saturating power; each 100 grain measures being equivalent to 1 grain of dried carbonate of soda. The results are arranged in double columns, showing separately, in grains of dried carbonate of soda, the degree of acidity or alkalence per 1000 grain-measures, and the amounts per hour. 500 grains of urine were usually operated upon; but if the urine was very dilute 1000 grains; and if very concentrated and scanty 250 grains were employed.

VI. *The Appearance of the Urine.* The condition of the

\* See table in Bird's *Urinary Deposits*, 5th edition, p. 60.



urine as to clearness or turbidity, *when passed*, and the colour, were also recorded. Frequently, too, the appearance on cooling or standing was noted, but the results do not appear in the following tables.

To complete the record, the times of the meals and their nature were chronicled.

The condition of the body as to exercise, occupation and sleep was also notified, but inasmuch as a single statement will suffice for all the particulars, the details are not here recorded, so as not too greatly to complicate the tables.

The mode of life of the subject of experiment was kept as nearly as possible uniform during the time of observation. He usually rose at seven, breakfasted at eight, dined at two, sometimes at four; and took no further solid food until breakfast next morning. He retired to rest at one in the morning; so that when the days of observation were successive there were but six hours of sleep. As to occupation and exercise there were necessarily some variations, but these were reduced to a minimum. Variously engaged in-doors until ten or eleven in the morning, moderate out-of-door exercise was afterwards taken until one or two. After dinner occupation was sedentary for two or three hours; then moderate out-of-door exercise was taken for one or more hours. Care was taken to avoid any violent or protracted exertion on the one hand or a complete inactivity on the other. Walking exercise for an hour or two did *not* produce any perceptible effect on the results.

The experiments are divided into six sets; each set embracing from three to seven days; and the results for the separate days are collected into a single table of averages, which shows the mean quantities for the days composing the set. The observations on the reaction, however, are given in detail for each separate day, and form a companion table to each table of averages.

The first observations were made on ordinary mixed food. They form two sets of four and seven days respectively, and there are added some odd days, which could not be united together to form a distinct set.

*Effect of Mixed Diet.*

The first set embraces four days, on which hourly observations were made from seven a.m. to eight a.m. next morning (except of course the hours of sleep, which form a single observation), a period of twenty-five hours.



TABLE I. Mixed food. Breakfast at Eight, dinner at Four. Mean of four days, not consecutive. (viz. Sept. 30, Oct. 4, Oct. 13, Oct. 21, 1858.)

Time of day	Hourly flow In grains	Density	Solids per hour In grains	Acidity		Alkalinity		Appearance	Remarks	Diet
				Per 1000 grain measure In grs. of dried carb. soda	Per hour measure In grs. of dried carb. soda	Per 1000 grain measure In grs. of dried carb. soda	Per hour measure In grs. of dried carb. soda			
7-8	514	1023.4	27.70	1.70	0.83	...	...	Each time clear, rich amber.		Breakfast at 8. Tea with dried toast and broiled bacon, or eggs, or pork chop.
8-9	770	1023.5	40.61	0.92	0.66	...	...	Each time clear, amber.		
9-10	902	1021.0	43.38	...	...	0.64	0.60	{ Twice clear and twice cloudy, pale greenish amber. }	{ Three times alkaline and once neutral. }	
10-11	1025	1019.8	46.57	0.22	0.22	0.87	0.94	{ Three times clear, once cloudy, pale greenish amber. }	{ Twice alkaline, twice faintly acid. }	
11-12	1125	1017.6	42.39	0.39	0.33	0.38	0.55	{ Each time clear, paler amber. }	{ Three times acid, once faintly alkaline. }	
12-1	915	1020.0	40.78	0.45	0.35	...	...	Clear, pale amber.		
1-2	1087	1017.0	36.38	0.66	0.62	...	...	Clear, pale amber.		
2-3	772	1020.8	32.71	1.00	0.64	...	...	Clear, pale amber.		
3-4	882	1020.4	29.87	1.24	0.77	...	...	Clear, pale amber.		
4-5	475	1024.3	26.39	1.19	0.58	...	...	Clear, pale amber.		Dinner at 4. Meat, potatoes, bread, cheese, beer.
5-6	2605	1006.2	31.97	0.20	0.40	0.58	1.37	Clear, pale straw.	{ Three times acid and once strongly alkaline. }	
6-7	960	1016.5	34.08	...	...	0.99	1.00	Muddy, yellowish.		
7-8	912	1018.7	37.28	...	...	0.83	0.87	Very muddy, yellowish.		
8-9	1095	1019.0	46.08	...	...	0.53	0.60	Muddy, yellowish.		
9-10	1740	1014.4	44.95	0.40	0.49	0.26	0.58	Clear, pale amber.	{ Once neutral, once alkaline, twice acid. }	At 9 two cups of coffee, without sugar or cream.
10-11	1505	1014.6	43.01	0.82	1.06	...	...	Clear, pale amber.	{ Two days. }	
11-12	605	1021.2	29.78	1.88	1.11	...	...	Clear, pale amber.	{ Two days. }	
12-1	510	1023.4	28.52	1.77	0.89	...	...	Clear, pale amber.	{ Two days. }	
1-7	681	1015.0	19.73	1.30	0.74	...	...	Clear, reddish amber.	{ Asleep. }	
7-8	355	1022.0	17.93	1.74	0.59	...	...	Clear, rich amber.	{ Two days. }	



On these four days the urine became alkaline both after breakfast and after dinner; and the effect of dinner is observed to be more intense, as well as more enduring, than that of breakfast. In constructing this and the succeeding tables of means a difficulty arose as to how to deal with those hours which on some of the days exhibited an acid, and on others an alkaline urine, such for example as from ten to eleven and eleven to twelve. The plan adopted has been to take a separate mean for the acid days and a separate mean for the alkaline days. This will explain why at these hours the urine is made to appear both acid and alkaline. Any obscurity or inconvenience arising from this will be obviated by a study of the companion tables, which give *in extenso* the daily results for the acidity and alkalinity.

TABLE II. exhibits the hourly Variation of Reaction for the days composing Table I. The Plus sign is prefixed when the urine was Acid, and the Minus sign when Alkaline.

	Sept. 30, First day		Oct. 4, Second day		Oct. 13, Third day		Oct. 21, Fourth day		Diet	
	Per 1000	Per hour	Per 1000	Per hour	Per 1000	Per hour	Per 1000	Per hour		
7-8	+1.88	+0.90	+2.16	+0.81	+1.20	+0.83	+1.56	+0.80	Breakfast at 8. Tea with sugar and cream; dried toast with broiled bacon, or eggs, or pork chop.	
8-9	+0.90	+0.77	+1.46	+0.94	+0.28	+0.21	+1.00	+0.74		
9-10	-1.00	-0.95	-0.64	-0.55	-0.84	-0.81	0.00	0.00		
10-11	-1.32	-1.45	+0.20	+0.21	-0.42	-0.44	+0.24	+0.22		
11-12	-0.38	-0.55	+0.68	+0.45	+0.09	+0.13	+0.42	+0.42		
12-1	0.00	0.00	+0.94	+0.52	+0.16	+0.15	+0.72	+0.75		
1-2	+0.41	+0.28	+1.18	+0.62	+0.64	+0.81	+0.42	+0.78		
2-3	+0.22	+0.15	+2.28	+1.03	+0.88	+0.68	+0.62	+0.72		
3-4	+0.32	+0.30	+2.52	+0.76	+1.40	+0.77	+0.72	+1.25		
4-5	+1.28	+0.66	+2.36	+0.83	+0.80	+0.40	+1.56	+0.83		Dinner at 4. Meat, potatoes, bread, cheese,
5-6	+0.06	+0.28	+0.26	+0.33	-0.58	-1.37	+0.28	+0.59		
6-7	-0.84	-0.88	-0.20	-0.15	-1.48	-1.30	-1.46	-1.68		beer.
7-8	-1.30	-1.79	-0.76	-0.58	-1.00	-0.97	-0.25	-0.14		
8-9	-0.62	-0.86	-0.78	-0.78	-0.56	-0.58	-0.18	-0.15		At 9 two cups of coffee with- out sugar or cream.
9-10	+0.36	+1.02	+0.86	+0.45	-0.26	-0.58	0.00	0.00		
10-11	+0.60	+1.77	+1.22	+1.05	+1.20	+1.27	+0.44	+0.86		
11-12	+0.54	+2.02	+1.00	+1.55	+2.28	+1.27	+1.48	+0.96		
12-1	+0.96	+1.39	+1.70	+1.18	+1.62	+0.89	+1.92	+0.92		
1-7	+1.16	+0.97			+0.74	+0.69	+1.86	+0.80		
7-8					+1.24	+0.51	+2.24	+0.67		



On the first day a slight luncheon, consisting of two thin pieces of bread and butter and a glass of water was taken at two. This accounts for the slow degrees by which the acidity recovered its ordinary level after breakfast.

About a pint of porter was taken between nine and eleven on the first night, and some bread and butter with tea between nine and ten on the second night. For this reason the urines passed after ten o'clock, on the first and second nights, are not reckoned in the table of means. Previous to these four days the condition of the urine had been examined at short intervals on five other days after breakfast, and on four days after dinner. On each day the urine became alkaline after dinner. After breakfast it became alkaline three times; but remained acid, in a diminished degree however, on the remaining two days.

The times of change from acid to alkaline, and back again from alkaline to acid, having now been ascertained with tolerable certainty, it was thought unnecessary to carry out so rigidly the very laborious plan of hourly observation throughout the entire day. In the succeeding experiments, therefore, hourly observations were only made at the critical periods, when the reaction was oscillating; but when the acidity was steadily rising, or had attained its usual level, observations were made every two hours. By this modification the experiments could be carried on with comparative ease, and continued for several consecutive days.

The effect of mixed food was again subjected to observation during seven days, all consecutive but one. Two meals a day were taken, and no alcoholic drinks.



TABLE III. Mixed food. Breakfast at Eight, dinner at Two. Mean of seven days, all consecutive but one.  
(March 8, 9, 10, 11, 12, 14, 15).

Time of day	Hourly flow	Density	Solids per hour	Acidity		Alkalinity		Appearance	Remarks	Diet
				Per 1000	Per hour	Per 1000	Per hour			
7-8	340	1024.91	19.55	1.54	0.52	...	...	{ Clear, amber; nearly always depositing lithates on cooling or standing. }		Breakfast at 8. Meat, coffee or tea, bread and butter.
8-9	520	1024.70	29.27	0.92	0.47	...	...	{ Clear, amber; generally depositing lithates. }		
9-10	850	1020.84	39.22	0.58	0.43	0.95	0.83	{ Four times cloudy, three clear, yellowish. }	{ Five times alkaline, twice acid. }	
10-11	1010	1019.93	44.34	0.34	0.33	0.62	0.66	{ Yellowish; twice turbid, five times clear, and once depositing lithates. }	{ Three times alkaline, three times acid, and once neutral. }	
11-12	1340	1017.58	45.24	0.52	0.47	...	...	{ Clear, pale amber; only depositing lithates once. }	{ Five times acid, twice neutral. }	
12-2	1090	1018.97	41.43	0.87	0.75	...	...	{ Clear, amber; once depositing lithic acid, and once lithates. }		
2-3	730	1024.00	38.69	1.12	0.72	...	...	{ Clear, amber; twice depositing lithates on cooling. }		Dinner at 2. Meat, potatoes, bread, cheese, water.
3-4	3440	1006.66	38.79	0.26	0.45	0.12	0.49	Clear, pale straw.	{ Three times acid, once neutral, and twice alkaline. }	
4-5	1170	1015.62	41.21	0.30	0.38	1.39	1.45	{ Six times turbid, once clear, yellowish. }	{ Six times alkaline, once acid. }	
5-6	790	1022.89	41.09	0.46	0.32	1.89	1.47	{ Six times very turbid and yellowish, once clear. }	{ Six times alkaline, once acid. }	
6-7	890	1023.27	49.01	0.00	0.00	1.54	1.38	Six times turbid, once clear.	{ Six times alkaline, once neutral. }	
7-9	910	1022.77	47.44	0.55	0.48	...	...	Clear, amber.		On two evenings three cups of water; another evening one cup, and three evenings nothing, either solid or liquid, after dinner.
9-11	850	1021.46	37.66	0.93	0.77	...	...	Clear, amber.		
11-1	610	1022.05	28.53	1.07	0.62	...	...	Clear, amber.		
1-7	350	1023.05	15.53	1.30	0.38	...	...	Clear, reddish amber.		
7-8	320	1024.50	17.75	1.55	0.45	...	...	Clear, rich amber.	Asleep. (Five days).	



TABLE IV. exhibits the Variations in Reaction for the several days composing Table III. (The Plus and Minus signs used as before).

Time of day	March 8, First day		March 9, Second day		March 10, Third day		March 11, Fourth day		March 12, Fifth day		March 14, Sixth day		March 15, Seventh day		Diet
	Per 1000	Per hour	Per 1000	Per hour	Per 1000	Per hour	Per 1000	Per hour	Per 1000	Per hour	Per 1000	Per hour	Per 1000	Per hour	
7-8	+ 1.92	+ 0.65	+ 1.12	+ 0.43	+ 0.92	+ 0.35	+ 1.52	+ 0.44	+ 2.00	+ 0.58	+ 1.76	+ 0.65	?	?	
8-9	+ 1.74	+ 0.80	+ 0.22	+ 0.17	+ 0.10	+ 0.05	+ 1.00	+ 0.44	+ 1.04	+ 0.50	+ 1.40	+ 0.78	+ 0.95	+ 0.43	Breakfast at 8. Tea, dried toast with meat.
9-10	+ 0.40	+ 0.29	- 0.82	- 1.07	- 1.00	- 0.88	- 0.70	- 0.46	- 1.12	- 0.84	+ 0.76	+ 0.58	- 1.12	- 0.94	
10-11	+ 0.48	+ 0.46	- 0.42	- 0.72	- 0.94	- 0.89	0.00	0.00	+ 0.24	+ 0.20	+ 0.62	+ 0.65	- 0.52	- 0.38	
11-12	+ 0.42	+ 0.52	0.00	0.00	0.00	0.00	+ 0.82	+ 0.79	+ 1.00	+ 0.84	+ 0.85	+ 0.76	+ 0.52	+ 0.42	
12-2	+ 0.73	+ 0.82	+ 0.15	+ 0.29	+ 0.46	+ 0.83	+ 1.08	+ 0.88	+ 1.40	+ 0.91	+ 1.40	+ 0.80	+ 0.88	+ 0.62	
2-3	+ 1.04	+ 0.94	+ 0.41	+ 0.36	+ 0.48	+ 0.46	+ 1.62	+ 0.89	+ 2.04	+ 1.00	+ 0.28	+ 0.71	+ 1.16	+ 0.66	Dinner at 2. Meat, potatoes, bread, cheese, water.
3-4	+ 0.10	+ 0.42	- 0.15	- 0.41	- 0.10	- 0.48	+ 0.20	+ 0.70	+ 0.76	+ 0.68	+ 0.30	+ 0.38	0.00	0.00	
4-5	- 1.68	- 1.28	- 2.66	- 2.21	- 1.16	- 2.06	- 0.64	- 0.80	- 0.60	- 0.78	+ 0.46	+ 0.32	- 1.64	- 1.74	
5-6	- 1.66	- 0.83	- 4.12	- 2.60	- 1.60	- 1.50	- 1.24	- 1.20	- 0.72	- 0.52	+ 0.00	0.00	- 2.00	- 2.14	
6-7	- 1.36	- 0.98	- 2.60	- 2.34	- 2.08	- 1.81	- 0.88	- 0.88	- 1.14	- 1.14	0.00	0.00	- 1.20	- 1.16	
7-9	+ 0.58	+ 0.54	+ 0.12	+ 0.14	+ 0.30	+ 0.37	+ 0.70	+ 0.60	+ 0.84	+ 0.59	+ 0.56	+ 0.46	+ 0.90	+ 0.67	
9-11	+ 0.77	+ 0.83	+ 0.40	+ 0.49	+ 0.68	+ 0.88	+ 1.18	+ 0.90	+ 0.92	+ 0.92	+ 1.14	+ 0.72	+ 1.44	+ 0.65	
11-1	+ 0.53	+ 0.62	+ 0.21	+ 0.53	+ 1.08	+ 0.65	+ 1.48	+ 0.70	+ 1.56	+ 0.64	+ 1.56	+ 0.59	?	?	
1-7	+ 0.42	+ 0.37	+ 0.85	+ 0.84	+ 1.30	+ 0.47	+ 1.68	+ 0.42	+ 1.48	+ 0.38	+ 1.52	+ 0.29	+ 1.88	+ 0.37	
7-8	+ 1.12	+ 0.43	+ 0.92	+ 0.35	+ 1.52	+ 0.44	+ 2.00	+ 0.58	?	?	?	?	+ 1.68	+ 0.44	



The results obtained on these seven days correspond closely with the foregoing, but they are exhibited in a less exaggerated degree. On the first and sixth days the urine after breakfast maintained its acidity, though on the first it was greatly reduced. On the sixth day the effect of both breakfast and dinner was comparatively small. On all the other days the urine became alkaline after both meals. The succession of events after each meal was quite uniform throughout. In an hour or two the acidity of the urine began to decline, and it sank to a minimum or changed to alkalinity at the second, third, or fourth hours; then, beginning to recover, the acidity gradually increased in degree until it attained its ordinary level. No departure from this sequence of events occurred, even as an exception.

What may be the circumstances which cause the very considerable inequalities between the several days, and between this set of observations and the preceding, — why a meal one day should only produce a slight depression of the acidity, another day render the urine neutral or faintly alkaline, and a third day change it for several hours to a strongly alkaline reaction, — is not capable of complete answer. But several of the disturbing causes have revealed themselves in the course of these observations, and will be discussed later on.

The effect of mixed food was further ascertained on four additional days, on which the times of emission of the urine were so irregular that the day tables could not be collected into one table of averages. On three of these, instead of being confined to two meals a day, the subject of experiment partook of four meals, which was according to his customary habit of life; and at dinner and supper he was allowed a pint of ale.



TABLE V. *Mixed food. Four meals a day. A pint of ale with dinner and supper. (March 18).*

Time of day	Hourly flow	Density	Solids per hour	Acidity		Alkalinity		Appearance	Remarks	Diet
				Per 1000	Per hour	Per 1000	Per hour			
7-40-9	260	1034.16	20.67	2.40	0.62	...	...	Clear, rich amber.	Depositing lithates abundantly on cooling. Depositing lithates abundantly on cooling. Depositing lithates on standing some hours. Depositing lithates on long standing.	Breakfast at 8-20. Tea, dried toast, meat.
9-10	550	1027.52	35.20	0.72	0.39	...	...	Clear, rich amber.		
10-11	540	1025.24	31.64	0.94	0.51	...	...	Clear, rich amber.		
11-2	460	1025.92	27.78	1.42	0.65	...	...	Clear, rich amber.		
2-4-30	890	1013.48	27.76	0.72	0.64	...	...	Clear, rich amber.	Not depositing on standing. Not depositing on standing.	Dinner at 2. Meat, potatoes, bread, cheese, ale.
4-30-6	400	1027.50	25.60	...	...	0.30	0.12	Clear.		
6-7	590	1027.80	38.05	...	...	1.40	0.82	Turbid.	Thick on passing.	Two cups of coffee and three pieces of bread and butter.
7-11	1150	1018.20	48.76	0.38	0.44	...	...	Clear, amber.	Not depositing.	
11-1	1260	1010.56	30.74	0.66	0.38	...	...	Clear, amber.	Not depositing.	At 11-30 bread and cheese and ale.
1-7	830	1009.64	18.92	0.80	0.66	...	...	Clear, amber.	Not depositing.	



TABLE VI. Mixed food. Four meals. A pint of ale with dinner and supper.  
(March 19).

Time of day	Hourly flow	Density	Solids per hour	Acidity Per 1000 Per hour	Alkalinity Per 1000 Per hour	Appearance	Remarks	Diet
7-9	330	1026.64	20.39	?	...	Clear, amber.	Depositing on cooling.	Breakfast at 8. Coffee, dried toast, meat.
9-10	760	1026.10	46.13	0.00	0.00	Clear, amber.	Not depositing.	
10-11	970	1021.50	48.50	0.15	...	Clear, amber.	Not depositing.	
11-2	790	1022.50	41.31	0.33	...	Clear, amber.	Not depositing.	
2-4	1430	1010.50	34.74	0.47	...	Clear, pale amber.	Not depositing.	Dinner at 2-15. Meat, potatoes, bread, cheese, ale.
4-6	1140	1017.00	45.14	...	0.58	Clear, yellowish amber.	Not depositing.	
6-8.30	710	1028.00	46.30	...	0.32	Clear, pale amber.	Not depositing.	Tea at 9. Bread and butter. Supper at midnight. Meat, bread, ale.
8.30-10	1000	1022.50	52.20	0.20	...	Clear, pale amber.	Not depositing.	
10-12	1120	1016.50	42.78	0.63	...	Clear, pale amber.	Not depositing.	
12-8	350	1027.00	22.05	1.52	...	Clear, deep reddish amber.	Depositing on cooling.	

TABLE VII. Mixed food. Four meals. A pint of ale with dinner and supper.  
(March 20).

Time of day	Hourly flow	Density	Solids per hour	Acidity Per 1000 Per hour	Alkalinity Per 1000 Per hour	Appearance	Remarks	Diet
8-9.30	420	1027.00	26.41	1.28	...	Clear, amber.	Depositing on cooling.	Breakfast at 9. Coffee, meat, bread and butter.
9.30-10.25	750	1025.50	45.47	0.88	...	Clear, amber.	Depositing on cooling.	
10.25-12.25	1230	1020.00	57.31	...	0.51	Clear, amber.	Not depositing.	
12.25-2	1030	?	?	0.14	...	Clear, amber.	Not depositing.	
2-3	4150	1004.00	38.67	0.20	...	Clear, very pale straw.	Not depositing.	Dinner at 1. Meat, bread, cheese, potatoes, greens, ale. Two cups of coffee and bread and butter at 5-45. Supper at 9. Meat, bread, cheese, ale.
3-5.30	910	1021.50	45.50	...	0.58	Clear, amber.	Not depositing.	
5.30-6.15	950	1023.50	51.96	0.72	...	Clear, amber.	Not depositing.	
6.15-8.35	2100	1012.75	59.85	0.43	...	Clear, pale amber.	Not depositing.	
8.35-11	2680	1006.50	40.47	0.34	...	Clear, straw.	Not depositing.	
11-7	425	1022.50	22.57	1.28	...	Clear, reddish amber.	Not depositing.	



TABLE VIII. *Mixed food. Two meals a day. Breakfast at 8-45, dinner at Two. No alcoholic drinks. (Jan. 31).*

Time of day	Hourly flow	Density	Solids per hour	Acidity Per 1000 Per hour	Alkalinity Per 1000 Per hour	Appearance	Remarks	Diet
7-8	330	?	?	2.24	...	Clear, rich amber.	Depositing on standing.	Breakfast at 8-45. Tea, meat, bread and butter.
8-9	400	1030.0	27.96	2.00	...	Clear, amber.	Depositing on standing.	
9-10	670	1027.0	42.71	1.00	...	Clear, amber.	Depositing on standing.	
10-11	700	1025.0	40.74	0.76	...	Clear, pale amber.		
11-12	850	1024.5	48.45	1.04	...	Clear, pale amber.		
12-2	660	1026.0	40.26	2.20	...	Clear, amber.		
2-3	530	?	?	2.33	...	Clear, amber.	Depositing in two hours.	Dinner at 2. Meat, bread, potatoes, cheese, water.
3-4	850	1020.0	39.61	1.12	...	Clear, amber.		
4-5	760	1023.5	41.57	0.00	0.00	Faintly cloudy.		
5-6	660	1027.0	41.51	0.00	0.00	Faintly cloudy.		
6-7	520	?	?	1.37	...	Clear, amber.		At 9 a cup of weak coffee without sugar or cream.
7-9	1400	1017.0	50.40	1.20	...	Clear, pale amber.		At 11 two cups of weak coffee with- out sugar or cream.
9-11	570	1029.0	37.47	1.82	...	Clear, amber.		
11-1	3720	1005.0	42.92	0.32	...	Clear, straw.		
1-7	394	1020.0	18.17	1.46	...	Clear, deep reddish amber.		
7-8	375	?	?	1.65	...	Clear, rich amber.		



It is seen by Tables V., VI. and VII. that moderate use of malt liquor did not perceptibly affect the results. A supper of meat and bread with a pint of ale had not the power of lowering the acidity of the night urine; on the contrary, the discharge of acid per hour was considerably above the average in Table III. for the nights on which no supper was taken; and the acidity per 1000 was at least as high as the general average. The effect of breakfast was decidedly less when a meat supper had been taken the night before.

In Table VIII. may be recognized a very unsusceptible day—more so than any met with during the whole course of the observations.

### 2. *The Effects of purely Vegetable Food.*

Two sets of observations were made with a view of ascertaining how far a diet exclusively composed of vegetable matters (excluding sweet and subacid fruits) affected the reaction of the urine.

In the *First Set*, which included four days, there was always taken a hearty supper of mixed food the night before. Only two of the days were consecutive, the others alternated with days on which a purely animal or a mixed diet was used. The observations extended from seven in the morning until about eleven at night.



TABLE IX. Vegetable food only. Mean of four days, not consecutive.  
Breakfast at Eight, dinner at Four.

Time of day	Hourly flow	Density	Solids per hour	Acidity Per 1000 Per hour	Alkalinity Per 1000 Per hour	Appearance	Remarks	Diet
7-8	490	1027.10	31.15	2.08	1.20	Clear, amber.		
8-9	750	1026.87	47.28	1.80	1.35	Clear, amber.		Breakfast at 8.
9-10	940	1025.00	54.54	1.20	1.14	Clear, amber.		Tea or coffee
10-11	1600	1017.10	58.75	0.63	1.00	Clear, pale amber.		with sugar only,
11-12	2250	1013.00	56.07	0.56	1.19	Clear, pale amber.		and bread.
12-2	1080	1019.25	50.62	1.23	1.32	Clear, amber.		
2-4	580	1026.00	34.89	2.30	1.30	Clear, rich amber.		
4-5	420	1028.00	29.01	3.11	1.29	Clear, rich amber.		Dinner at 4.
5-6	3570	1007.10	36.85	0.49	1.12	Clear, straw.		Vegetable soup,
6-7	880	1018.00	36.70	0.90	0.79	Clear, amber.		bread, rice, sugar,
7-8	650	1024.75	37.12	0.85	0.57	Clear, amber.		celery, water.
8-9	660	1025.50	38.74	2.39	1.44	Clear, amber.		
9-11	730	1024.62	40.45	2.19	1.45	Clear, amber.		



TABLE X. exhibits the Variations in Reaction on the several days composing Table IX.

Time of day	Jan. 20, First day		Jan. 21, Second day		Jan. 25, Third day		Jan. 27, Fourth day		Diet
	Per 1000	Per hour	Per 1000	Per hour	Per 1000	Per hour	Per 1000	Per hour	
7-8	2.10	?	2.90	1.24	2.20	1.08	2.16	1.30	Breakfast at 8. Tea or coffee, with sugar but no cream, with four or five slices of bread.  Dinner at 4. A vegetable soup, bread, rice, sugar, celery, water.
8-9	1.96	1.76	1.70	1.09	1.92	1.25	1.62	1.33	
9-10	1.36	1.49	1.20	1.02	1.12	0.98	1.14	1.08	
10-11	0.68	1.09	0.80	1.24	0.48	0.93	0.58	0.76	
11-12	0.66	1.32	0.68	1.33	0.34	1.14	0.58	0.99	
12-1	1.32	1.62	1.36	1.15	1.14	1.30	1.12	1.22	
1-2	2.08	1.56	2.12	1.07	2.10	1.20	2.80	1.37	
2-3	?	?							
3-4									
4-5			2.77	1.15	3.78	1.40	2.80	1.34	
5-6		1.44	0.20	0.98	1.00	1.11	0.27	1.27	
6-7	3.30		0.96	0.71	0.65	0.60	1.10	1.07	
7-8			1.98	1.22	0.42	0.25	1.28	0.89	
8-9	3.70	1.70	1.30	1.24	1.30	1.24	2.60	1.61	
9-10	3.12	0.85	2.12	1.60	1.28	1.23	2.26	2.15	
10-11					?	?	?	?	



On none of these four days did the urine become alkaline either after breakfast or dinner; indeed the hourly discharge of acid suffered scarcely an appreciable declension after breakfast on the first two days. And throughout the entire set, the effect of the meals was strikingly less than with mixed food. Small as the effect was however, its reality is beyond question; and on the third day, after dinner, the depression nearly approached the neutral line. I do not lay any stress on the falling off in the *acidity per 1000 parts*, because the urine invariably became more aqueous after meals, and the falling off in the *degree* of acidity might seem attributable to this cause alone.

If we compare the hourly discharge of acid with the hourly discharge of solids, the depression of acidity after the meals, so faintly indicated in the above tables, comes out much more strongly, as will be shown hereafter.

To isolate more completely the operation of vegetable food, it was thought desirable to subsist for several days continuously on a purely vegetable diet, and to avoid especially taking supper on the previous nights. The articles of diet used were bread, rice, potatoes, carrots, lettuce and endive, with coffee and tea without cream. No alcoholic drinks were ever used during these experiments unless when specially mentioned.



TABLE XI. Vegetable food only. Mean of five days: three of these were consecutive, and the other two succeeded to days of mixed diet, on which dinner had been taken at Two p.m., after which no solid food was taken until next morning. Breakfast at Eight, dinner at Two.

Time of day	Hourly flow	Density	Solids per hour	Acidity		Alkalinity		Appearance	Remarks	Diet
				Per 1000	Per hour	Per 1000	Per hour			
7-8	274	1029.20	17.95	1.89	0.52	...	...	{ Clear, amber; nearly always depositing lithates on cooling.		Breakfast at 8. Coffee (with sugar and no cream) with bread.
8-9	480	1026.20	28.34	1.38	0.65	...	...	{ Clear, amber; often depositing lithates on cooling.		
9-10	920	1018.11	33.54	0.35	0.22	0.72	0.60	{ Three times clear, once turbid from phosphates.	{ Twice alkaline, once neutral, and once acid.	
10-11	820	1021.39	35.28	0.90	0.60	...	...	{ Clear, pale amber; sometimes depositing lithates.		
11-12	1670	1011.38	42.19	0.63	1.04	...	...	{ Clear, paler amber; not depositing at all.		
12-2	1780	1013.26	44.56	0.69	1.09	...	...	{ Clear, pale amber; not depositing at all.		
2-4	1630	1017.81	40.17	1.07	0.85	0.28	0.24	Clear, pale amber.	{ Four times acid, once alkaline.	Dinner at 2. Vegetable soup, salad, bread, potatoes, carrots, water.
4-6	1370	1016.20	39.31	0.72	0.37	0.50	1.14	{ Twice turbid from phosphates, three times clear.	{ Three times acid, twice alkaline.	
6-7	1250	1020.33	43.34	0.62	0.44	0.00	0.00	{ Clear, pale amber in each case.	{ Once neutral, twice acid.	
7-9	1340	1019.32	57.66	0.78	0.92	...	...	Clear, pale amber.		Two or three glasses of water between 7 and 11.
9-11	690	1022.93	36.57	1.30	0.92	...	...	Clear, amber.		
11-1	1020	1015.81	34.31	0.72	0.69	...	...	Clear, pale amber.		
1-7	360	1020.09	14.04	1.38	0.43	...	...	Clear, reddish amber.		
7-8	280	?	?	1.63	0.42	...	...	Clear, rich amber.	(Asleep).	



TABLE XII. exhibits the Variations in the Acidity for the four days composing Table XI.  
(The Plus and Minus signs used as before).

Time of day	Feb. 4, First day		Feb. 5, Second day		Feb. 6, Third day		Feb. 7, Fourth day		March 16, Fifth day		Diet
	Per 1000	Per hour	Per 1000	Per hour	Per 1000	Per hour	Per 1000	Per hour	Per 1000	Per hour	
7-8	+ 2.25	+ 0.70	+ 1.54	+ 0.53	+ 1.75	+ 0.42	...	...	+ 1.68	+ 0.44	Breakfast at 8. Coffee with sugar, but no cream, and bread.  Dinner at 2. Vegetable soup, salad, bread, potatoes or carrots, water. Between 7 and 11 two or three cups of water, but no solids.
8-9	+ 2.44	+ 1.00	+ 1.30	+ 0.79	+ 1.16	+ 0.53	...	...	+ 0.64	+ 0.28	
9-10	+ 0.70	+ 0.45	0.00	0.00	- 0.36	- 0.45	...	...	- 1.08	- 0.75	
10-11	+ 1.54	+ 0.86	+ 0.80	+ 0.67	+ 0.10	+ 0.17	...	...	+ 0.36	+ 0.28	
11-12	+ 0.76	+ 1.06	+ 0.73	+ 1.79	...	...	+ 0.80	?	+ 0.42	+ 0.72	
12-2	+ 0.68	+ 1.33	+ 0.96	+ 1.29	+ 0.37	+ 1.08	...	...	+ 0.76	+ 0.68	
2-4	+ 1.60	+ 0.93	+ 1.20	+ 1.22	- 0.28	- 0.42	+ 0.54	+ 0.74	+ 0.94	+ 0.53	
4-6	+ 0.84	+ 0.37	- 0.60	- 0.81	- 0.40	- 1.47	+ 0.86	+ 0.58	* + 0.46	+ 0.15	
6-7	+ 0.96	+ 0.72	0.00	0.00	+ 0.50	+ 0.59	+ 0.96	+ 1.09	+ 0.92	+ 0.60	
7-9	+ 0.80	+ 0.98	+ 0.44	+ 1.03	?	?	...	...	+ 0.90	+ 0.58	
9-11	+ 1.40	+ 1.12	+ 1.76	+ 1.19	+ 1.16	+ 1.07	+ 1.30	+ 0.64	+ 1.00	+ 0.59	
11-1	+ 0.76	+ 0.73	+ 0.88	+ 0.77	+ 0.90	+ 0.80	+ 0.34	+ 0.46	+ 1.42	+ 0.43	
1-7	+ 1.27	+ 0.50	?	?	+ 2.16	+ 0.40	+ 0.69	+ 0.40	...	...	
7-8	+ 1.54	+ 0.53	+ 1.75	+ 0.42	+ 2.53	+ 0.38	+ 1.25	+ 0.46	+ 1.00	+ 0.29	

\* The urine from four to six was passed in two portions. That from four to five was alkaline to the degree of 0.30 per 1000, and 0.27 per hour; but between five and six it had become acid to the degree of 0.76 per 1000, and 0.42 per hour; so that the united products gave an acid reaction as represented in the table.



On the first day of this set the acidity fell in a very marked degree both after breakfast and dinner; on the second, the urine became neutral after breakfast for an hour, and alkaline and cloudy for two hours after dinner, and continued neutral yet another hour; on the third day it was alkaline after both meals; and on the fifth morning a breakfast of four pieces of dried toast and a cup of coffee without milk made the water passed two hours after turbid from phosphates, and highly alkaline; it lost its acid reaction after dinner also on this day. Here lies abundant evidence that vegetable food is able to depress the reaction of the urine equally with mixed diet.

### 3. *Effect of purely Animal Food.*

As in the case of vegetable food, two sets of experiments were made to ascertain the power of purely animal food to depress the acidity of the urine. The first set did not embrace the twenty-four hours, but began at seven in the morning and ceased about ten in the evening. Four days are included in this set; three of them alternated with days on which vegetable food only was taken at breakfast and dinner, but a supper of mixed food with ale or porter was taken at night.



TABLE XIII. *Purely animal food. Mean of four days, not consecutive. Breakfast at Eight, dinner at Four.*

Time of day	Hourly flow	Density	Solids per hour	Acidity Per 1000 Per hour	Alkalinity Per 1000 Per hour	Appearance	Remarks	Diet
7-8	380	1029.80	21.69	2.52	0.88	{ Clear, amber; depositing lithates on cooling.		
8-9	720	1025.00	43.69	1.52	0.84	Clear, deep amber.		
9-10	1160	1023.75	61.06	0.64	1.03	Clear, amber.	{ Twice acid, twice alkaline.	
10-11	1110	1024.75	62.00	0.41	0.55	{ Three times clear, once turbid.	{ Three times acid, once alkaline.	Breakfast at 8. Meat, eggs, milk and water.
11-12	1030	1023.00	50.39	0.75	0.81	Clear, amber.		
12-2	940	1023.62	48.01	1.54	1.29	Clear, amber.		
2-4	860	1024.32	41.01	2.02	1.45	Clear, amber.		
4-5	740	1025.83	43.96	1.38	1.01	Clear, amber.		
5-6	1770	1014.66	53.13	0.38	0.53	Clear, pale amber.	(Three days).	Dinner at 4. Meat, cheese, milk, water.
6-7	1420	1022.00	70.44	...	0.59	{ Twice very turbid and yellowish, once clear.	(Three days).	
7-9	1640	1020.00	71.56	0.50	1.09	Twice turbid, once clear.	{ (Three days). Twice alkaline, once acid.	
9-10	1120	1026.50	69.30	0.67	0.74	Clear, amber.	(Two days).	



TABLE XIV. exhibits the Variations in the Acidity for the days composing Table XIII. (The Plus and Minus signs used as before).

Time of day	Jan. 24, First day		Jan. 26, Second day		Jan. 28, Third day		Jan. 19, Fourth day		Diet
	Per 1000	Per hour	Per 1000	Per hour	Per 1000	Per hour	Per 1000	Per hour	
7-8	+3.14	+0.77	+1.88	+1.15	+1.56	+0.78	+3.52	+0.84	Breakfast at 8. Eggs and meat, with milk and water.
8-9	+1.76	+0.68	+0.97	+1.07	+0.96	+0.91	+2.40	+0.66	
9-10	-0.32	-0.22	+0.68	+1.10	+0.60	+0.96	-0.44	-0.31	
10-11	+0.20	+0.14	+0.52	+0.68	+0.52	+0.84	-1.36	-1.05	
11-12	+0.88	+1.23	+0.70	+0.80	+0.96	+0.91	+0.48	+0.29	
12-2	+0.86	+1.19	+1.28	+1.11	+1.20	+1.24	+2.84	+1.62	
2-4	+0.98	+1.47	+2.00	+1.36	+1.74	+1.44	+3.30	+1.55	
4-5	+1.23	+0.99	+1.24	+0.94	+1.68	+1.10	+0.38	+0.68	Dinner at 4. Meat, cheese, milk and water.
5-6	+0.90	+1.03	+0.10	+0.16	+0.16	+0.41	-0.62	-0.62	
6-7	-0.15	-0.17	-0.88	-1.28	-0.73	-1.25	+1.58	+1.39	
7-8	} +05.1	+1.09	-0.94	-1.32	-0.95	-1.54	} +1.88	+1.93	
8-9			-0.14	-0.16	-0.62	-0.78			
9-10	...	...	+0.94	+1.03	+0.40	+0.46	...	...	
10-10½	...	..	...	...	+0.94	+ .94	...	...	

The urine became alkaline each day after dinner, and twice after breakfast. On the third day, after breakfast, the urine sustained its acidity with a scarcely perceptible diminution; though, as compared with the height to which it rose after the supposed alkaline tide had passed off, the depression was sufficiently marked, and still more marked if the hourly excretion of solids be taken into account, at the contrasted periods.

In order to observe the effect of a longer continuance of an animal diet, the supper of mixed food on the previous night was discontinued, and for three successive days animal food alone was taken. The following tables exhibit the results obtained.



TABLE XV. *Animal food only. Mean of four days, three of which were consecutive. Breakfast at Eight, dinner at Two.*

Time of day	Hourly flow	Density	Solids per hour	Acidity Per 1000 Per hour	Alkalinity Per 1000 Per hour	Appearance	Remarks	Diet
7-8	270	?	?	2.40	...	Clear, amber.		Breakfast at 8. Meat and eggs, milk, water.
8-9	510	1027.00	33.60	1.66	...	Clear, amber.	{ Twice neutral, once acid and once alkaline.	
9-10	870	1020.50	47.52	0.23	0.20	Clear, amber.		
10-11	1570	1019.75	49.75	0.49	0.44	{ Three times clear, once cloudy.	{ Twice acid, once neutral and once alkaline.	Dinner at 2. Meat, cheese, milk, water.
11-12	1470	1021.81	54.07	0.91	...	Clear, pale amber.		
12-2	950	1025.31	53.32	1.41	...	Clear, amber.		
2-4	940	1024.50	53.00	1.39	...	Clear, amber.	{ Twice acid, twice alkaline.	A glass of water between 9 and 11.
4-6	1300	1021.20	59.79	...	0.47	Muddy, yellowish.		
6-7	1110	1026.10	64.49	0.56	0.46	{ Twice muddy and yellowish, twice clear.		
7-9	1210	1021.00	61.01	0.81	...	Clear, amber.		
9-11	1080	1024.90	62.42	1.05	...	Clear, amber.		
11-1	2150	1013.25	53.87	0.51	...	Clear, straw.		
1-7	480	1021.12	22.24	1.43	...	Clear, reddish amber.		
7-8	310	?	?	2.59	...	Clear, rich amber.		



TABLE XVI. exhibits the Variations in the Acidity for the several days composing Table XV.

Time of day	Feb. 3, First day		Feb. 7, Second day		Feb. 8, Third day		Feb. 9, Fourth day		Diet
	Per 1000	Per hour	Per 1000	Per hour	Per 1000	Per hour	Per 1000	Per hour	
7-8	+1.25	+0.46	+2.53	+0.38	+3.68	+0.86	+2.13	+0.79	
8-9	+0.78	+0.48	+1.45	+0.58	+2.36	+1.10	+2.04	+1.12	Breakfast at 8. Meat or eggs, or both, milk, water.
9-10	-0.20	-0.39	0.00	+0.00	+0.46	+0.37	0.00	0.00	
10-11	0.00	0.00	-0.44	-0.35	+1.56	+1.22	+0.40	+0.43	
11-12	+0.22	+0.73	+0.80	+0.60	+1.28	+1.18	+1.37	+1.17	
12-2	+1.04	+1.33	+1.44	+1.03	+1.20	+1.34	+2.00	+1.33	
2-4	+0.46	+0.51	+1.80	+1.37	+1.50	+1.61	+1.80	+1.51	Dinner at 2. Meat and milk, cheese, water.
4-6	-0.60	-0.83	-0.76	-0.81	-0.45	-0.42	-0.07	-0.27	
6-7	-0.57	-0.97	-0.34	-0.36	+0.52	+0.52	+0.60	+0.42	
7-9	+0.14	+0.17	+1.14	+1.21	+0.96	+1.39	+1.00	+1.07	A cup of water between 9 and 11.
9-11	+0.62	+0.76	+1.24	+1.24	+1.32	+1.27	+1.00	+1.15	
11-1	+0.21	+0.49	+1.06	+1.18	+0.40	+1.14	+0.37	+0.85	
1-7	+1.09	+0.58	+1.52	+0.75	+1.04	+0.61	+2.06	+0.64	
7-8	+2.25	+0.72	+3.68	+0.86	+2.13	+0.79	+2.30	+0.72	

The urine lost its acid reaction each day, both after breakfast and dinner, except on the third day, and even then it was reduced nearly to the neutral line.

The diet used in these two sets of observations was variously composed. For breakfast, a mutton or pork chop, or beef steak, and water; sometimes eggs and boiled milk, and once fried sole and boiled milk. For dinner, roast fowl, partridge or hare, broiled salmon, oysters, beef steak, mutton chop, cheese and milk.

*On the Effect of Food in general.*

Inasmuch as all our ordinary articles of diet, whether they be drawn from the vegetable or the animal kingdom, present the same elements of composition beneath a great diversity of outward condition, it might naturally be anticipated that their effects on the system would not be greatly dissimilar.

In every article of diet, as offered by the hand of nature—in the flesh of beasts, birds, fish, and all other forms of animal life; in the seed of the various orders of cereals; in the succulent stems, roots and tubers of fresh



vegetables; in the sweet and subacid fruits of our own and tropical climates — in all these, may be found representatives of the albuminous, oleaginous and saccharine groups of alimentary substances, together with certain saline ingredients — phosphates, sulphates, chlorides and carbonates, having for bases soda, potash, lime and magnesia — whose universal presence sufficiently attests the essential importance of their functions.

Nevertheless the wide differences of proportion which are known to exist in the admixture of the organic and inorganic substances in various articles of diet, and especially in the contrasted classes of animal and vegetable foods, prepare us to expect that in the final products of the vital operations there will be found certain peculiarities attributable to the nature of the aliment. One of these is the reaction of the urine, which is notoriously dissimilar in carnivorous and herbivorous creatures, being acid in the former and alkaline in the latter. And this difference has been universally laid to the account of the food of the two classes.

The urine of the herbivora is alkaline, it is asserted, because they feed upon matter rich in alkaline carbonates, citrates and tartrates, all of which appear in the urine as carbonates. And it has been shown that when these creatures are made to fast, their urine becomes acid.

Dr. Cl. Bernard\* was able to trace still more decisively the connection between the reaction of the urine and the nature of the food. He found that when rabbits (whose urine is normally alkaline) were fed for some time on an exclusively animal diet, they passed an acid urine; and that its alkalinity was not restored until a vegetable diet was substituted. Dogs also, when restricted to a vegetable fare, secreted an alkaline urine, turbid from deposition of phosphates; but when restored to animal flesh

\* *Comptes Rendus*, 1846, tom. 22, p. 534.



their urine resumed its natural clearness and acid reaction.

It is more easy to reconcile the experiments detailed in the preceding pages with the first of these considerations than with the second. All food was found essentially to affect the reaction of the urine alike, but, contrary to what one would expect, animal food produced usually a stronger and more enduring impression than vegetable food. Yet it may be pointed out as worth notice, that of the three *consecutive days* of exclusively animal and exclusively vegetable diet, the greatest effect in the former was on the first day, and it fell progressively on the second and third days; whereas the reverse took place on the days of vegetable food. On the first day the urine did not become alkaline at all; on the second it was neutral after breakfast and alkaline for two hours after dinner; on the third day it was strongly alkaline for an hour after breakfast and for three hours after dinner.

Ordinary food, whether it was purely animal, purely vegetable, or, as was more usual, an admixture of the two, was invariably found to cause a diminution in the amount of acid separated by the kidneys. In the tables there is record of thirty-two days on which the urine was examined both after breakfast and after dinner (with the exception of one day on which the observations did not commence until after dinner); and I have notes, in addition, of the state of the urine on five other days after breakfast and on four days after dinner. The following table shows how often the urine became neutral or alkaline, or sustained its acidity, after these two meals, with various kinds of food.



TABLE XVII. shows the reaction of the urine at the time of greatest depression after breakfast and dinner on mixed food (twenty days breakfast and nineteen days dinner); vegetable food (eight days breakfast and nine days dinner); and animal food (eight days breakfast and dinner).

	Mixed diet			Vegetable diet			Animal diet		
	Alk.	Neut.	Acid	Alk.	Neut.	Acid	Alk.	Neut.	Acid
Breakfast	12	2	6	2	1	5	3	2	3
Dinner...	17	2	0	3	0	6	8	0	0

Out of seventy-two meals the urine became alkaline after forty-five, neutral after seven, and sustained its acidity after twenty. After thirty-six breakfasts the urine became alkaline seventeen times, neutral five times, and remained acid fourteen times. After thirty-six dinners the urine became alkaline twenty-eight times, neutral twice, and it continued acid six times.

The effect of dinner is thus seen to be very considerably greater than that of breakfast. Indeed after a dinner of mixed or animal food the urine never failed to sink to the neutral line, its acidity being preserved only with vegetable food. The cause of the distinction lay, probably, simply in the fact, that breakfast was a much lighter meal than dinner, and its impression on the system consequently smaller.

But although the urine preserved its acidity frequently after breakfast, and sometimes even after dinner, there was a notable falling off in the intensity of its reaction, whether regard be had to the degree of acidity per 1000 parts, or the quantity discharged per hour. In one set of experiments only, namely the first on vegetable food, does this appear at first sight somewhat doubtful, and seem to require some additional explanation. The decline in the hourly discharge of acid after breakfast, as seen in Table IX., seems so small that a doubt might be cast on its reality; but if we compute the hourly separation of acid as it stands related to the hourly discharge of solids, we



shall find that the fall after breakfast is brought out in its true prominence, as the following table shows.

TABLE XVIII. The first column is a transcription of the hourly discharge of acid from Table IX. The second column shows the per-centage of acid on the solids at successive hours from seven a.m. to four p.m. (Breakfast at Eight).

Time of day	Acid discharged per hour	Acid corresponding to 100 grains of solids
7-8	1.20	3.87
8-9	1.35	2.87
9-10	1.14	2.11
10-11	1.00	1.72
11-12	1.19	2.12
12-2	1.32	2.32
2-4	1.30	3.82

By this table it is made evident that the solid constituents of the urine, or what, for brevity, may be called the *solid urine*, became steadily less and less acid after breakfast until eleven o'clock; from that time its acidity rose as steadily until dinner. At eleven o'clock the solid urine had less than one-half the acidity it possessed before breakfast, or just before dinner.

The same result is brought out after dinner, and in about the same degree. Taking the two hours before dinner, and the sixth and seventh hours after dinner, every 100 grains of solid residue had an acidity of 3.65; whereas during the third and fourth hours after dinner (the period of the supposed *alkaline tide*) the solid residue of the urine had but 1.82 per cent. of acid.

The apparently exceptional cases, where meals do not appear to lower the acidity at all, or where the hourly discharge rises even for a while after a meal, are thus made conformable to the general result. The taking of a meal greatly increases the excretion of solids by the kidneys; and even if these be of diminished acidity, the quantity passed per hour may overbalance this diminution, and, for a while, actually cause an increased hourly discharge



of acid. For example, on the 25th of January (Table X.), the hourly separation of acid before breakfast was 1.08. During the first hour after breakfast it rose to 1.25; but if the solid matters be brought into consideration, it is found that there is here in reality a depression, instead of an elevation, of the acidity. At the former period the solids had a per-centage of acid of 3.81; whereas at the latter, the per-centage had declined to 3.17.

I have been thus at pains to prove that the evidence of the first set of experiments on vegetable food is unequivocal as to the depressing effect of vegetable food on the reaction of the urine, not because other proof was wanting — the second set abundantly supplies that — but in order to uphold the conclusion contended for, that all the observations on the individual under experiment were perfectly concurrent; and that the law, so far as he was concerned, came out absolute and without exception, *that food lowered the acid reaction of the urine.*

There is considerable advantage in comparing the oscillations of the urinary free acid with the oscillations in the hourly discharge of solid urine. It is from this point of view that we can best see the relations of the former to the state of the blood. It is not necessary here to go into the proof that the degree of alkalinity of the blood regulates strictly the rising and falling acidity of the urine. By adding to the alkalescence of the blood through artificial means, as by exhibiting caustic or carbonated alkalies internally, we are able to depress in corresponding proportion the acidity of the urine. On the other hand, also, by exhibiting acid (although this seems less readily accomplished) we can similarly heighten the reaction.

By taking the solid urine as a standard of comparison, we avoid two fallacies which respectively affect the determinations per 1000 parts and the determinations per hour. We escape, in the first place, oscillations arising from *mere*



*dilution*, which sometimes sink the determinations per 1000 grains almost to zero, although the separation of acid at the time is high. In the second place, we avoid oscillations arising from the *varying activity of the kidneys*.

I shall presently have to call attention to the columns showing the hourly discharge of solid urine. It will be sufficient here to state, that, after meals, the hourly discharge of solids rises very considerably, that at periods remote from meals it sinks again, and that during sleep it falls to a minimum. So great is the oscillation from this sole cause that it gives an entirely false complexion to the columns indicating the acid separated per hour. It makes it appear as if the acidity, after having recovered from the first depression consequent on a meal, rose for a few hours to an unusual height, and then fell away again a second time — as if, in fact, an *acid tide* succeeded to the *alkaline tide* previously to the subsidence of the reaction to its normal level. If the eye be cast along the columns of hourly discharge of acid in the various tables, this will be seen at a glance. During the hours of continued abstinence after dinner it comes into especial prominence. It is seen that when the alkaline tide has subsided, and the acid reaction become re-established, there is exhibited for about two hours an unusually high rate of discharge; in fact higher than at any period of the twenty-four hours; and that after this again there appears a constant fall which is maintained and increased during the subsequent hours of abstinence and sleep. All the tables concurrently demonstrate this (see Tables I., III., XI. and XV.), and without the correction here indicated it would lead to an erroneous interpretation of facts.

Now if we take the *solid urine*, and calculate its acidity per 100 parts, we find that after recovering from the depression of the alkaline tide the acidity shows no sign of



falling off again until after the next meal. The determinations in Table III. are especially worthy of attention in reference to this point. This table gives the mean numbers for seven successive days, on which the utmost endeavour was made to avoid irregularity or inaccuracy; and the densities were all taken by the specific gravity bottle. If we now place, side by side, the numbers indicating the hourly discharge of acid and the numbers indicating the per-centage of acid in the solid urine, from the hour of seven p.m., when the alkaline tide subsided, to eight o'clock next morning, just before breakfast, the two series of numbers will be seen to be entirely different. In the former there is a rise and then a fall; in the latter there is a continued rise. For comparison, the acidity per 1000 grains of the liquid urine is also added.

*TABLE XIX. shows the varying results obtained by computing the acidity of the urine in three different ways, namely, per 1000 grains of the liquid urine; per hour; and per 100 grains of the solid urine. (The two first columns copied from Table III.) Dinner at Two p.m.*

Time of day	Per 1000 grains of liquid urine	Per hour	Per 100 grains of solid urine
7-9 p.m.	0.55	0.48	1.02
9-11 "	0.93	0.77	2.02
11-1 "	1.07	0.62	2.13
1-7 a.m.	1.30	0.38	2.37
7-8 "	1.55	0.45	2.50

From the third column, with which the first also is in agreement, we may conclude that when the alkalescence of the blood regains its level, after the influence of a meal has passed off, it continues nearly at that level until the next meal; or, rather, there appears a tendency to a gradual diminution in the alkalescence of the blood as fasting is prolonged; but I scarcely dare to rely with certainty on the calculation for the determination of so nice a point. The other tables of means, Nos. I., XI. and



XV., support the main conclusion as uniformly as could be expected, if it be remembered that the densities were taken by a hydrometer, without correction for temperature, and not with that care and precision which would have been used had it been foreseen that they would have been employed for calculating the solids.

The rise in the hourly discharge of acid from nine to eleven and eleven to twelve (eighth, ninth and tenth hours after dinner) is, therefore, entirely due to the fact that the increased activity of the kidneys, called forth by the meal, persists for two or three hours after the blood, and by consequence the urine, has recovered its normal reaction.

So that by taking the solid urine as a basis for calculation, two distinct corrections have been shown to be necessary in reading the determinations of acidity per hour. By the first correction, the apparently doubtful or contradictory cases, where there was but a slight or no fall in the numbers after breakfast, are made to agree satisfactorily with the general law; and by the second, the apparent existence of an acid tide following in a few hours on the ebb of the alkaline tide is shown to depend on a fallacy.

*The duration and time-of-setting-in* of the alkaline tide were both subject to considerable variations from day to day, and they differed too for breakfast and dinner. Under the term alkaline tide is embraced the whole period of depressed acidity, whether the urine at the time was alkaline, neutral or only of diminished acidity.\*

The effect of breakfast appeared earlier than that of dinner, and was always distinctly perceptible at nine

\* It might be objected to this term, *alkaline tide*, that it is applied to urines which do not become alkaline. But, although in such instances the urine does not altogether lose its acidity, there is only a difference of degree between such and those in which the urine becomes actually alkaline. There is the same movement in both cases; but in the former it does not crop out from beneath the surface of the neutral line, whereas in the latter it makes itself sensible by a change of reaction.



o'clock, that is, within forty minutes after the conclusion of the meal. The urine, however, never became alkaline, nor even neutral, so soon. During the succeeding hour, from nine to ten, the alkaline tide usually culminated; but in about a third of the cases the point of least acidity was not reached until eleven o'clock. Then the tide turned; and from eleven to twelve the urine was found fast recovering its reaction, and about one the normal level was generally attained.

But although the acidity after breakfast was *depressed* for a period of from four to five hours, it was not *absolutely alkaline* usually for more than one hour; generally from nine to ten. Not unfrequently, however, it continued alkaline, and even increased in alkalescence, until eleven; and on one occasion it continued alkaline for three hours, that is, until noon.

After dinner, which usually occupied half an hour, the acidity maintained itself through the first hour (that is, the hour at the beginning of which dinner was taken), but declined during the second in varying degrees on different days; and on five occasions the urine became alkaline. During the third, fourth and fifth hours the alkaline tide ran in its greatest strength. On the third and fourth hours the urine was always (with two exceptions) found alkaline when the meal had been of mixed food or animal diet. On the fifth hour it was also nearly always alkaline, but not so invariably so as on the two preceding ones. At the end of the next (sixth) hour the tide had generally turned and the acid reaction been restored. This change appeared often to take place with considerable suddenness, and the rise of the acidity went on with such celerity that in two hours (that is, at the end of the seventh hour) it had reached the ordinary standard. Three hours was the usual duration of the alkalescent state of the urine after dinner; sometimes two hours, more rarely four hours, and



one occasion five hours. The amount of free alkali hourly discharged after dinner was, generally, not far from double the quantity observed after breakfast; so that in duration and intensity the effect of dinner proved about twice as great as that of breakfast.

*The Alkaline Urine of Food.*

The alkaline urine which followed the taking of food deserves special description. It is important, in the first place, to state that its alkalescence did not depend upon ammonia, but upon a fixed alkali. It had no ammoniacal smell; caustic potash failed to evolve any; and the phosphates which were thrown down in it did not, when freshly passed, contain any crystals of the ammoniaco-magnesian phosphate. Under the microscope the fresh deposit was always found to be amorphous. No effervescence could ever be observed in the urine on the addition of hydrochloric acid. As might have been anticipated, the occurrence of an alkaline reaction determined the precipitation of the earthy phosphates, and the urine, when passed, was frequently turbid. But this was not always so. Not unfrequently, especially after breakfast, the urine, although alkaline, retained its transparency. Generally such a urine was of feeble alkalinity and dilute; but now and then it was observed to be tolerably concentrated, highly alkaline, and still clear. All transparent alkaline urines were rendered immediately turbid by caustic ammonia and by heating, so that the transparency did not depend on the absence of earthy phosphates. It was also found that, in the turbid urines after subsidence of their deposits, caustic ammonia caused an additional precipitation.

Out of twenty-eight specimens of alkaline urine after breakfast, nineteen were more or less turbid and nine clear. Of sixty-four specimens alkaline after dinner, fifty-one were turbid and thirteen clear. The proportion of



clear alkaline urines after breakfast was, therefore, considerably greater than after dinner.

The degree of turbidity varied from a barely perceptible cloudiness to a thick muddy opacity. The deposit subsided quickly and left a clear, yellowish-amber supernatant liquor, often with a greenish tinge.

The *odour* of this urine was peculiar, and so distinctive that its alkaline reaction could with certainty be predicated, without the aid of test paper, simply by the sense of smell. It was altogether devoid of the characteristic urinous odour, and exhaled a strong sweetish aroma resembling that of the fresh urine of the horse. The more strongly alkaline it was, the more powerful was this odour, and *vice versa*.

The proportion of *alkaline and earthy phosphates* in the urine of the alkaline tide was found to be considerably increased. The quantity separated during the two hours preceding dinner and that separated during the third and fourth hours after dinner was subjected to comparison. The hourly separation of the *earthy phosphates* was found, on an average of six days, nearly doubled after dinner; and the *alkaline phosphates* rose from 3.47 grains to 4.90 grains per hour. This increase was not owing to the quickened activity of the secretory organs, for the proportion per 1000 of the liquid urine and the proportion per 100 grains of the solid urine exhibited an equally marked elevation.

The quantity of *uric acid* was ascertained for three periods on each of the seven days composing Table III., namely, in the urine of the alkaline tide after dinner (from four to seven); in the acid urine passed between nine and eleven; and lastly, in the urine of sleep. The average for the seven days, at each of these periods, may be seen from the following table.



TABLE XX. shows the mean amount of Uric Acid separated on the seven days composing Table III.—during the alkaline tide after dinner; from nine to eleven p.m.; and during the night.

Time	Uric acid per 1000 grains of liquid urine	Uric acid per hour	Uric acid per 100 grains of solid urine
4-7 p.m., alkaline tide	0·40	0·36	0·83
9-11 p.m., acidity restored	0·18	0·13	0·34
1-7 a.m., urine of sleep	0·39	0·10	0·60

The urine of the alkaline tide was, therefore, rich in uric acid (as calculated per 1000), rather more so even than the night urine, which in nearly every instance deposited urates copiously on cooling. The hourly quantity was almost three times greater than during the succeeding period when the acidity was restored (from nine to eleven), and more than three times greater than during sleep. The differences are not so great when the per-centage of uric acid in the solid residue is calculated; although, here, also, the alkaline urine gives notably the highest figure.

The urine of the alkaline tide may, therefore, in every sense be regarded as pre-eminently charged with uric acid.

The remarkable poverty of the urine in uric acid, from nine to eleven, not only as contrasted with the urine of the alkaline tide but also with that of sleep, is probably closely connected with the increased excretion of uric acid during the preceding hours of the alkaline tide. If it be true, as these results lead us to believe, that a diminished acidity or, *a fortiori*, alkalescence of the urine is very favourable to the separation of uric acid from the blood, and causes an increased quantity of it to pass through the kidneys, it follows that on the cessation of the alkaline tide the blood must be unusually poor in uric acid; and the separation of it by the kidneys therefore, on the



re-establishment of the acid reaction, must be proportionally diminished. It is also extremely probable that there is, to some extent, an increased *production* of uric acid in the blood after food, and that a portion of the increased elimination is due to this.

*Remote Effects of a Meal.*

Although, as we have seen, the immediate effect of a meal was to depress the acidity of the urine, the more remote consequence was to uphold and even to increase the acidity. It has already been pointed out, that if we take the amount of acid separated per hour as our standard of comparison, the quantity discharged was greater during the period immediately following the re-establishment of the normal reaction than at any other period either previous or subsequent. And this has been explained to have depended on the high activity of the kidneys at that time. But there is another and still more remote effect of a meal, which comes out under different relations, and which is seen most distinctly, when a comparison is made between the acidity of the urine on mornings succeeding supperless nights and that of the urine on mornings following a hearty supper. In the former case, the mean hourly rate of acid discharged between seven and eight a.m. was only 0.51; in the latter it was 0.88, or nearly double. And not only was the hourly discharge thus increased, but even the degree of acidity per 1000 showed a slight rise—the mean numbers being for the mornings after supperless nights 1.83, and for mornings after a supper 2.15. This latter calculation, however, did not always exhibit results in accordance with this general mean, and exceptions occurred; but for the *hourly* calculation, all the separate results were consistent, sometimes in a greater, sometimes in a less degree, with the general mean.

It is important to bear these particulars in mind, for



they enable us to explain certain irregularities and discrepancies which appear when the effect of a meal on one day is compared with the effect of a similar meal on another day. For it frequently comes to pass that the remote effect of a previous meal interferes with, or completely masks the immediate effect of a succeeding one. Here, no doubt, lies the cause of the slight effect produced by vegetable food in the first set (Table IX). The remote effect of the highly animalised diet of the previous days masked the immediate effect of the meals on the days following.

It is a marked feature in these experiments, that, although there was the greatest constancy and certainty in the successive changes of reaction, there were very considerable — indeed the widest — differences in the *absolute amounts* of free acid or free alkali separated by the kidneys at corresponding hours after a meal on different days. For example, in Table IV., the acid passed between eight and nine a.m. on the first day was more than four times greater than on the third day at the same hour; and this, although the breakfast on the two days was as nearly as possible the same both in quantity and quality. Two considerations may be offered in explanation of this discrepancy. First, there was the supper on the night preceding the first day; secondly, digestion and absorption of the meal was probably going on more rapidly on the third morning than on the first, from the comparatively empty state of the vessels, consequent on the long previous abstinence.

But these explanations by no means meet all the cases of irregularity, as is shown by a comparison of the state of the urine from ten to eleven a.m. on the fourth and fifth days of the same table. On the fourth the urine was neutral at this period, whereas on the fifth it was acid to the extent of 0.20 per hour; yet on both days the antecedents, so far as food was concerned, were identical. Doubt-



less there are secret causes of unequal action in the animal system of so subtle a nature as to be altogether beyond our present powers of appreciation. I would suggest, however, that the state of the body in respect to repose and exercise, and the external temperature, probably exert an important influence.

Muscular juice is highly acid, and its quantity is, in all likelihood, greatly increased by exercise; and it seems not improbable, as Vogel has suggested, that the degree of acidity of the urine has some connection with the quantity of this acid of muscle thrown into the blood, and so through the kidneys out of the body.

The external temperature, too, by quickening or retarding the cutaneous transpiration and the respiratory function, may affect the amount of acid circulating and generated in the blood.

Differences in the nature of the food, especially as regards the proportion of earthy and alkaline phosphates, may almost with certainty be named as operative in causing differences in the effects of different meals on the reaction of the urine.

This and other matters connected with this part of the subject will come under discussion again when the inquiry is entered on — *Why* should a meal depress the acidity of the urine?

*The amount of free acid separated in the course of the twenty-four hours* was found, on an average of nineteen days, to be sufficient to neutralise 14·10 grains of dried carbonate of soda, or an average of 0·58 grains per hour. The maximum quantity was 22·34, and occurred under a purely animal diet; the minimum was 5·90 under a mixed diet. Some days were found exhibiting throughout a feeble acidity; others a high acidity, quite independently of the nature of the diet. The average amounts of acid per



twenty-four hours for the different sets were: mixed diet (Tables I. and III.), 14·21 and 10·30; purely vegetable diet (Table XI.), 15·36; and purely animal food (Table XV.), 18·03. These numbers show that the daily amount of acid eliminated by the kidneys was not much or uniformly affected by the nature of the food. The smallest numbers occurred under mixed food; but I am not disposed to attribute this to the nature of the food so much as to other circumstances, inasmuch as on some of the days of mixed food the acidity ruled unusually high, but the averages (especially of those of Table III.) were greatly reduced by one or two days of very low acidity.

*The degree of acidity per 1000 grains* is of more importance, practically, than the amount per hour, inasmuch as the occurrence of urinary deposits depends on it. If no liquids were taken, the degree of acidity after the passing away of the alkaline tide, gradually increased until food was again taken. The highest acidity, therefore, was always found after the longest fasting, or just before breakfast and dinner. Between seven and eight in the morning the urine was uniformly found excessively acid, invariably depositing abundance of urates on cooling. The night urine likewise, except when liquids were taken on going to bed, was highly acid and sedimentary. It may be easily conceived, therefore, that this is the period most favourable to the formation of renal and vesical concretions. The urine flows slowly and rests for a lengthened period in the bladder, while its excessive acidity and concentration diminish its solvent powers over oxalate of lime, uric acid and the urates — the three substances most liable to unnatural precipitation.

When no liquids were taken before going to bed the urine of sleep had an acidity varying from 1·50 to 2·16 per 1000. In the morning, before breakfast the numbers ran from 1·50 to 2·80 and 3·00, rising on one occasion to 3·68



per 1000. The mean acidity, taking all the hours during which the urine flowed acid, was 1.13 per 1000; if the hours of sleep, the two hours before dinner and the hour before breakfast be excluded, the mean acidity for the remaining hours of the acid flow falls to about 0.80 per 1000.

*The amount of free alkali passed in the twenty-four hours* varied according to the duration and intensity of the alkaline tide. On the nineteen days represented in Tables I., III., XI. and XV. the urine was alkaline, on an average, for more than three and half hours each day, and contained a quantity of free alkali equal in saturating power to 3.32 grains of dried carbonate of soda. The mean quantity discharged per twenty-four hours, with mixed food, was 4.14 grains for the first set and 4.72 grains for the second (Tables I. and III.); for vegetable food, 1.71 grains (Table XI.); and for animal food, 1.68 grains (Table XV.)

The numbers for the separate days ranged from zero to 9.35 grains, and great irregularities prevailed throughout, even when the days were consecutive and the diet the same.

It is to be remarked that the days of mixed diet showed a greater discharge of free alkali than those of purely animal or purely vegetable diet. This corresponds with the lower figure representing the free acid on those days.

*The hourly discharge* of free alkali oscillated from 0.00 to 2.60; and it usually ranged between 0.50 and 1.00.

*The degree of alkalinity per 1000 grains* varied also in the same manner. The highest grade observed was 4.12; but the usual numbers were from 0.40 to 1.60.

In comparing the *effects of the three different kinds of diet* it must be owned that the results are very contradictory. In the first set of experiments on vegetable food the urine did not once become alkaline (Table IX.) nor



even neutral. This must be attributed to the remote effect of the flesh meat diet used on the alternate days. In the second set (Table XI.), however, vegetable food was found to possess a great and apparently increasing power of depressing the acidity of the urine when persevered in for successive days. So that the daily average discharge of alkali for the four successive days of vegetable food was raised even above that for successive days of animal food—the mean total amount of free alkali per day in the former case being 1·71 grains and in the latter 1·68 grains. In the first set of observations on animal food, however, the mean daily discharge of free alkali was 2·17 grains.

But the effect of mixed food was found on an average considerably greater than that of purely vegetable or purely animal food, both in duration and intensity—the mean daily separation of free alkali being 4·14 grains and 4·72 grains respectively for the first and second sets. This contradictory result appears at present quite inexplicable, for there did not seem to be any difference in the rate of absorption nor in the quantity of the meals.

*The degree of acidity before meals* (in other words, the remote effect) was found greatest after animal food, while the difference between purely vegetable food and mixed food was not very considerable; the numbers on the whole, however, being favourable to vegetable food. In the subjoined table may be seen the degree of the acid reaction during the hours of fasting, before breakfast and dinner, with the three kinds of food.

*TABLE XXI. exhibits the Acidity of the Urine before meals, with the different kinds of food.*

	From 1 to 8 a.m. (Before breakfast)		12 noon to 2 p.m. (Before dinner)	
	per 1000	per hour	per 1000	per hour
Mixed food	1·47	0·53	0·85	0·74
Vegetable food	1·52	0·42	1·01	1·20
Animal food	2·01	0·70	1·46	1·27



Before proceeding to discuss the explanation to be offered of the power of a meal to depress the acidity of the urine, attention must be called to the variation in the amount of solid matter—in other words, solid urine—secreted at different hours of the day. The numbers were obtained, as already explained, by calculation from the density. With the exception of the seven days included in Table III., the specific gravity was taken by a hydrometer, and not with that scrupulous care, nor under that correction which is required for calculating the solids. While therefore able to state that all the tables show results remarkably concurrent, I am inclined to place most reliance on the determinations in Table III., which were made with the necessary precautions. On passing the eye down the columns of solids in the six tables of means, it is seen that the quantity per hour began to increase within an hour after breakfast, that is, between eight and nine, and went on increasing rapidly until eleven. It remained stationary until about noon, and then began to fall, and continued to diminish until dinner (see especially Tables I., IX. and XIII., when dinner was at four), and even for an hour after. At the end of the second hour after dinner there was usually, but not always, a slight rise. During the third hour there was a very decided rise, which went on increasing until the fifth or sixth hour, about which time it reached the culminating point. From that time the discharge of solids fell gradually until bedtime, and sank to the lowest point during the hours of sleep. All the tables of means exhibit the same procession of numbers, whatever the nature of the food might be. Exceptional instances occurred, it is true, here and there; but with so great a multiplicity of details it was impossible altogether to avoid errors, from faulty observation, calculation or record. The contradictory facts, however, were quite insignificant beside the overwhelming majority of concurrent observations.



Now, what does this increase in the solids of the urine after a meal indicate? It evidently marks the passage of digested food into the blood. We see reflected in the renal secretion, as in a mirror, the flow of aliment into the blood. First the small beginning, then the increase, then the full tide, followed by a gradual ebb as the last portions of the food continue to be taken up from the lower divisions of the alimentary canal; until at length, after all has been absorbed, the blood returns to its condition as before a meal.

No doubt the passage of food into the blood is not the only circumstance that causes an increased separation of solid urine. Active functional exercise, whether of muscle or brain, probably quickens the activity of the kidneys by throwing into the blood an increased quantity of effete materials — the products of the destructive metamorphosis of the muscular and nervous elements. The invariably great and sudden rise in the solid urine from eight to nine in the morning is certainly not entirely the effect of breakfast, as it is incredible that digestion and absorption should have made such progress in forty minutes. The awakening of the whole system from the torpor of sleep — the aroused mental and muscular activity, and the consentaneous acceleration of the circulation and respiration — contributed, unquestionably, in producing the result. No such sudden rise is seen at any time in the subsequent hours, nor after dinner.\*

The question now arises: How far is the depressing action of food on the acidity of the human urine a universal phenomenon? It is impossible to solve this question

\* It may be noted that the increase in the hourly secretion of solid urine after dinner was not so prominently marked as after breakfast. I believe this arose from the almost complete inactivity usually observed by the subject of experiment for two or three hours after the former meal, whereas after breakfast his condition was one of activity.



except by greatly multiplied observations conducted on the principle of hourly determinations. But the facts at present known warrant the statement, that at least some healthy persons, whose urine presents no appreciable peculiarity, suffer constantly a diminished acidity of urine after meals, and that the secretion may flow alkaline and turbid for four and six hours daily without the least evidence of impaired function.

I am disposed to believe that the depression of the acidity of the urine after a meal is of universal occurrence; but, at the same time, observation leads me to conclude that there are very great differences in the degree or intensity of the phenomenon in different individuals — these differences arising, apparently, from fixed peculiarities of constitution. Without pretending to be able to point out all of these, or to estimate their influence, the following may be indicated as probably tending to produce that effect.

1. The cutaneous transpiration varies greatly in different persons. Those with an active skin eliminate a large amount of acid by the cutaneous surface, and consequently have less for removal by the kidneys. In such persons the alkaline tide might be expected to flow with greater intensity than where the skin is habitually dry and torpid. The sweat seems incapable of ever changing from acid to alkaline, for I have invariably found it sour, even when the urine has been rendered strongly and uninterruptedly alkaline by bicarbonate of potash for four and five weeks continuously.

2. The respiratory capacity of individuals varies. This bears on the present question in this way. Recent observations, especially those of Dr. E. Smith,\* show that shortly after a meal the respiratory function is materially

\* See his Papers read before the Royal and Medico-Chirurgical Societies during the present year, 1859.



quicken; more carbonic acid is exhaled, and consequently more oxygen absorbed into the blood. Those persons in whom this increase takes place promptly after a meal, and is unusually great, would probably show but a feeble alkaline tide, because the oxygen, thus thrown in excessive quantity into the blood, would cause increased formation of acid, and in this way mask the contrary effect of the food.

3. The quicker the digestion and the absorption of a meal, the greater *cæteris paribus* would be its depressing effect on the acidity of the urine.

It seems not unlikely that the two last mentioned causes determine by their mutual relation in an especial manner the degree of intensity assumed by the alkaline tide. A rapid absorption of a meal and a small amount of respiratory acceleration would present the combination most favourable to an intense depression of the urinary acid. On the contrary, a slow absorption of a meal and a prompt exaltation in the respiratory functions would so balance the opposing tendencies that the reaction of the urine would suffer only a minimum of depression.

These modifying circumstances apply not only to differences between individuals, but, in a minor degree also, to differences in the same individual at different times.

This seems the proper place to offer some considerations which may explain why alkaline urine after meals is not oftener met with in actual experience; and whence arise the grave discrepancies in the experience of different observers in this country and in Germany.

It is essential, in order to trace the effect of a meal, to *examine the urine at short intervals*. For if this be neglected the acid product secreted before and after the period of depression becomes mixed in the bladder with the urine of the alkaline tide, and when the whole is ejected by micturition it is found acid, even although a



portion of it was highly alkaline as it left the pelvis of the kidney. And micturition seems to occur, in the usual course, at such intervals as most effectually to prevent the alkaline urine of food from being observed unless by an unusual accident. The first micturition of the day usually takes place on leaving bed, and the urine is highly acid. The second does not occur, unless the bowels be emptied after breakfast, for some five or six hours; and it includes some very acid urine secreted before and immediately after breakfast, together with the urine of the morning alkaline tide, as well as the secretion with recovered acidity which is produced for two or three hours after the subsidence of the alkaline tide. Such a urine is sure to be acid, notwithstanding an alkaline flow through the kidneys for one or two hours. The same thing occurs after dinner. The bladder is usually emptied before the meal, and then for a couple of hours the urine flows acid. If there be excessive potation the urine may require discharging at this period, and it will always be found acid. If, on the contrary, potation has been restricted, or the system drained of water at the time of the meal, the next micturition may be delayed an hour or two, so as to cut the alkaline tide in half. Even then the urine will be acid, unless the depression was unusually great. The next micturition may occur after tea, and the recovered acidity of the urine would then conceal the alkalinity of the portion secreted at the beginning of the period.

From these remarks it may be gathered that unless the product of the alkaline tide be isolated, by emptying the bladder before and after its flow, no reliance can be placed on observations concerning it. This is, I apprehend, the reason why the observations of Beneke and Vogel, and probably also those of Dr. Sellers, have failed to support the conclusions of Dr. Bence Jones.

In Dr. Beneke's experiments the bladder was not emptied



oftener than about five times in the twenty-four hours; and by comparing the times of the meals with the times of micturition, it becomes evident that it was impossible for him to obtain results other than nugatory. The urines he examined were mixed urines, and he did not in any wise isolate the secretion at the critical periods.

The same objection applies to the observations conducted under the supervision of Vogel. The urines were collected during three periods—namely between breakfast and dinner (morning urine), between dinner and evening (afternoon urine), and during the hours of night. All such urines would be acid mixtures; but it by no means follows that they did not pass through an alkaline state, possibly even of some hours duration.

So true is it that the existence of the alkaline tide may be concealed for an indefinite time, even from those who are in the constant habit of observing the state of the urine, unless the urinary product be, as it were, analysed by frequent micturitions, that the urine of the subject of these experiments, though under close observation for some years, was not once known to have departed from its usual acid reaction; and it took me almost by surprise to find the phenomena of the alkaline tide so strongly and so remarkably pronounced after such long and effectual concealment.

A second circumstance, which must be borne in mind, is the *remote* influence of meals. As already fully explained, this remote effect of a previous meal frequently altogether masks the immediate effect of a recent one; and this statement seems especially to apply to the effect of supper on the succeeding breakfast. For this reason it is well, in order to obtain distinct results, to fast for eight or ten hours, or more if night intervene, before taking the meal whose effect it is wished to observe.

Finally, we come to the inquiry: *Why should a meal*



*depress the acidity of the urine?* Dr. Bence Jones imputes it to the diversion of the acid present in the blood to the stomach for the purposes of digestion. When the stomach is empty its lining membrane is neutral, or nearly so, and the acid generated in, or thrown into, the blood passes off by the skin and kidneys, rendering the urine acid; but when food is taken, acid gastric juice is poured from the blood vessels into the stomach, and the alkalinity of the blood is consequently raised. This causes the kidneys to separate a less acid or even an alkaline product; but when digestion is completed, the gastric acid returns to the blood with the chyle, and the urine regains its normal reaction. So that the stomach and kidneys are antagonistic in their reaction, the former being least acid when the latter are most so, and *vice versa*. So plausible an explanation was at once adopted; and it is difficult to imagine that it may not have some operation in the way supposed, though, as I believe, it must be rejected as the main cause of the alkaline tide.

From Dr. Beaumont's twenty-fifth and twenty-sixth experiments, second series, we are led to conclude that sufficient gastric juice for the digestion of a meal is poured into the stomach within fifteen or twenty minutes after its ingestion; and that in half an hour, or an hour at most, the flow of acid into the stomach has ceased and absorption of the digested meal commenced. If this be so, the reaction of the urine ought to be most depressed within an hour or an hour and a half after a meal, instead of from two to five hours after. Moreover, how can it be explained, on this supposition, that the alkaline tide after dinner sets-in an hour or an hour and a half later than after breakfast?

But, whatever may be thought of the validity of these objections, is there not another solution more consonant with the facts observed? Is the alkaline tide not the



effect of the *absorption of a meal into the blood*, rather than of digestion? If it be true, as Liebig maintains, that the alkalescence of the blood — and in all animals that possess blood its reaction is alkaline — depends simply on the chemical composition of the alimentary substances, is there not here a solution for our question?

In his twenty-eighth Letter,\* Liebig points out that phosphoric acid and the alkalies are present in such proportion in bread, meat, and our ordinary food, that if we suppose them dissolved the alkalies invariably preponderate. Hence arises, he says, the alkalinity of the blood. If this be so, every meal that is dissolved and absorbed into the blood must increase the alkaline reaction of that fluid and raise it for a time above the natural level.

But it is well known that when salts of the fixed alkalies which have an alkaline reaction — such as carbonates, basic phosphates and borates, or vegetable salts, which become carbonates in the system — are artificially exhibited, they change the reaction of the urine from acid to alkaline; evidently from inducing an excessive alkalescence of the blood, which it is the function of the kidneys to diminish by allowing the excess to escape in the urine. Conformably to this hypothesis, the earthy and alkaline phosphates were found greatly increased in the urine after meals.

A meal, therefore, viewed in this light, is a dose of alkali, which, when digested and absorbed, necessarily adds to the alkalinity of the blood; and, as a more remote but equally inevitable consequence, lowers the acidity of the urine or, if in sufficient quantity, renders it actually alkaline. It has been already pointed out that the setting-in of the alkaline tide coincides, in point of time, with the passage of the digested food into the blood, as indicated by the increased amount of solid urine secreted

\* *Familiar Letters.* Letter 28.



by the kidneys; and as absorption goes forward and increases, the acidity of the urine diminishes more and more. It is nevertheless true that the subsidence of the alkaline tide is not synchronous with the cessation of absorption, for we have seen that the passage of food into the blood appears at its highest activity when the alkaline tide is beginning to ebb. This want of coincidence appears, *primâ facie*, to militate against the solution here offered; but it may be explained in two ways. Either it arises from the phosphatic salts being absorbed with more celerity than the rest of the food, and producing their effect before the other materials are all taken up; or, more probably, it depends on the increased absorption of oxygen by respiration, already noticed as occurring after a meal, which, after the lapse of five or six hours, by generating acid, counteracts the contrary effect of the food — in other words, from the remote effect of a meal overlapping the immediate effect.

If this solution be admitted, it brings all ordinary food into the same category with sub-acid fruits, which have long been acknowledged to possess the power, in virtue of their saline constituents, of rendering the urine alkaline; the only difference being that in the latter the effect is produced by salts, which become carbonates in the blood, and in the former by basic phosphates, which pass as such into the urine.\*

\* It must not for a moment be supposed that the urine is never alkaline (from fixed alkali) except after food. The urine not unfrequently loses its acid reaction in disease, independently of food, and presents to all appearance the characters of the urine of the alkaline tide after a meal. I have observed this character of the secretion repeatedly in the debilitated and anæmic condition which sometimes follows chronic subacute gout and obstinate subacute articular rheumatism; also in the course of some other protracted and exhaustive diseases that induce a chlorotic or spanæmic state; of which perhaps the most common is a certain form of atonic dyspepsia. In such cases the urine may be alkaline all the day through, though



The results of the foregoing observations may be summed up in the following propositions:—

1. The immediate and primary effect of a meal, whether of purely vegetable, purely animal, or mixed food, was, in from one to three hours to diminish the acidity of the urine; and very frequently to render it alkaline. The term "alkaline tide" is suggested to designate the period of depressed acidity.
2. The remote or secondary effect of a meal was to uphold and increase the acidity of the urine. This effect of a meal was especially observed over-night after supper.
3. The remote effect of animal diet appeared considerably greater than that of vegetable food. So that a highly animalised diet tends in the long run to heighten the acidity of the urine.
4. After breakfast, the greatest depression occurred at the second hour; and the period of depression continued from two to four hours.
5. After dinner, the greatest depression occurred at

this is very rare. In my experience I have not found such a condition continuing from day to day for any length of time, but rapidly passing away, not lasting more than some hours or a day or two; but perhaps returning again and again. Such urines must be carefully distinguished from ammoniacal urines, which invariably indicate some disorder in the urinary passages, generally in the bladder.

Another cause of alkaline urine is the immersion of the body in water. Homolle and Duriau found that after a bath the urine always lost its acid reaction, even when nitric acid had been added to the bath.—*Archiv. Génér.*, T. ii. 1856.

I am also convinced that an overworked and depressed state of the system promotes a diminished acidity of the urine; and that a high state of health and vigour tends to heightened acidity.

The explanation offered in the text, therefore, applies only to one particular case of alkaline urine, and must not by any means be taken as a general explanation.



the third, fourth and fifth hours, and lasted from four to six hours. The effect of dinner was greater, as well as more prolonged, than that of breakfast.

6. The effect of mixed and purely animal diet seemed almost identical. Vegetable diet, when used on alternate days with mixed or animal food, had a decidedly feebler effect; but when used continuously for several days successively its effect was equally powerful.
7. Alkaline urine after a meal owed its reaction to a fixed alkali. It was generally, but not always, turbid, when passed, from precipitated phosphates. Its odour resembled that of the fresh urine of the horse. It was richer in uric acid and in earthy and alkaline phosphates than the urine of fasting.
8. The depression of the acidity after a meal coincided in point of time with absorption rather than with digestion. The solids of the urine began to increase simultaneously with the declension of its acidity. So that the passage of food into the blood and the diminished acidity of the urine seemed to be connected together as cause and effect.

The following deductions appear also to be warranted:—

1. That the power of a meal to depress the acidity of the urine depends on its mineral constituents. These contain phosphoric acid and the alkalies in such proportion, that if we suppose them dissolved the alkalies invariably preponderate. Hence arises the alkalinity of the blood. If this be so, every meal that is dissolved and absorbed into the blood must for the time raise the alkalescence of that fluid above the natural level.



2. But the kidneys have the special function of regulating the degree of alkalescence of the blood. When it is too high they separate alkali, and the urine becomes alkaline; when it tends to become too low, on the other hand, they separate acid, and this gives to the urine its common acid reaction.
3. A meal then, in so far as its mineral ingredients are concerned, is but a dose of alkali, and its absorption causes, like any other dose of alkali, a depression of the acidity of the urine.
4. The emission of urine turbid with phosphates is, within certain limits, a natural phenomenon; and earthy phosphates constitute the only urinary deposit which can appear in the healthy urine *on passing*.
5. Urines may be divided into two chief classes:— First, *urines of fasting (urinæ sanguinis)*; secondly, *urines of food (urinæ cibi)*. Fasting urines are scanty and of high acidity; they present only one variety, namely, that of sleep, which differs from other fasting urines in possessing more colouring matter. The urines of food fall naturally into two divisions— those with a diminished, and those with a restored acidity; they are abundant in quantity. The urines of either class may be concentrated or dilute, according to the relation between potation and the requirements of the system in regard to water. So that *urinæ potūs* do not merit to be regarded as a distinct class. Most commonly the urine of micturition belongs exclusively to no division, but is a mixture of several kinds.



## APPENDIX.

On two days the effects of cane sugar and honey were tried. Neither seemed to produce any depression of the hourly quantity of urinary acid discharged. On the first day a quarter of a pound of loaf sugar was dissolved in water and taken at eight a.m. At two p.m. half a pound was taken in the same way, instead of dinner. No solid of any sort, or other liquid than water, was taken during the experiment.

On the second day half a pound of honey was taken for breakfast at eight in the morning, with water; and no solid food was again taken until the conclusion of the experiment.

The annexed tables exhibit the results obtained.



TABLE I. *Cane sugar. A slight supper taken the night before.*

Time of day	Hourly flow	Density	Acidity		Appearance	Diet
			Per 1000	Per hour		
7-8	285	1027.80	1.00	0.29	Clear, amber; depositing lithates on cooling. Clear, amber. Clear, amber. Clear, pale straw. Clear, pale straw, Clear, rich amber. Clear, straw. Colourless. Clear, pale straw. Clear, deep reddish-amber; depositing lithates on standing. Clear, deep reddish-amber; depositing lithates on standing. Clear, deep reddish-amber; depositing lithates on standing.	Quarter of a pound of loaf sugar, and water at 8.  Half a pound of sugar, and water at 2.
8-9	540	1025.16	0.92	0.46		
9-10	630	1022.00	0.68	0.43		
10-11	1730	1007.36	0.31	0.54		
11-12	2270	1006.24	0.18	0.41		
12-2	495	1021.24	1.12	0.55		
2-3	1530	1005.54	0.39	0.59		
3-4	*7780	1000.60	0.07	0.53		
4-6	1700	1006.84	0.32	0.54		
6-7	550	1026.32	1.00	0.55		
7-9	240	1029.36	2.36	0.56		
9-11	166	1030.32	2.16	0.36		

TABLE II. *Honey. No supper the night before.*

Time of day	Hourly flow	Density	Acidity		Appearance	Diet
			Per 1000	Per hour		
7-8	388	1024.64	1.48	0.57	Clear, amber; depositing lithates on cooling. Clear, amber; depositing lithates on cooling. Clear, amber; depositing lithates on cooling. Clear, amber; not depositing. Clear, amber; not depositing. Clear, pale amber; not depositing. Clear, pale amber; not depositing. Clear, rich amber; depositing lithates abundantly.	Half a pound of honey with water at 8.
8-9	387	1027.84	1.72	0.67		
9-10	455	1027.28	1.30	0.60		
10-11	730	1015.52	0.68	0.50		
11-2	660	1016.24	0.71	0.47		
2-4	1760	1004.66	0.26	0.46		
4-6	480	1016.44	0.70	0.34		
6-7½	284	1025.76	1.22	0.35		

\* This was really the product of forty minutes.



Cane sugar and honey do not seem to possess any power of diminishing the excretion of acid by the kidneys. The evidence is rather the other way; for although the tendency to a rise after breakfast on the two days is too slight to insist much upon, yet it is very notable that the honey and sugar prevented the fall that would otherwise have taken place from mere prolongation of the fasting. The hourly flow kept up without appreciable change until about the seventh hour after the saccharine meal; then there occurred a marked declension.

The absorption of the sugar and honey was far from rapid; for sweet eructations took place for four and five hours after their ingestion, showing that the stomach was still hampered with their presence. Some considerable difficulty was experienced in swallowing and keeping down these large doses. It is worthy of note, that the second dose of cane sugar produced a most copious, though evanescent, diuresis. Not less than 7780 grain-measures of a watery urine were produced in forty minutes, or at the rate of  $26\frac{1}{2}$  fluid ounces per hour, presenting a remarkable contrast to the flow five hours later, when only 166 grain-measures were secreted per hour, or at a rate *seventy times* slower than during the first period.



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