

SUMMARY OF RESULTS.  
Ca Expressed as mg. per 100 c.c.

Normal Human.		Normal Dog.		Human Rickets.		Dog Tetany.	
Serum Ca.	Per Cent. Diffusible Ca, %.	Serum Ca.	Per Cent. Diffusible Ca, %.	Serum Ca.	Per Cent. Diffusible Ca, %.	Serum Ca.	Per Cent. Diffusible Ca, %.
10.5	65	10.9	68	9.0	68	6.3	62
11.1	67	11.1	69	7.6	63	6.1	63
10.5	67	10.7	60			6.7	66
10.3	68	10.6	61				
11.0	72	10.2	69				
10.4	70						

These observations indicate that there is no change in the proportion of diffusible serum calcium in human rickets, or in experimental dog tetany.

138 (1720)

**The relation of acid base equilibrium in the body to excretion of phosphorus and calcium.**

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The relation of the acid base equilibrium in the animal body to calcium and phosphorus metabolism has been studied by a number of workers.<sup>1</sup> The significance of variation in the acid base equilibrium is undoubted, but considerable confusion is encountered, when an attempt is made to correlate the available results. A good many of the experiments have been done on small

<sup>1</sup> Gerhard and Schlesinger, *Arch. exp. Path. u. Pharm.*, 1899, xlii, 83.  
Fitz, Alsberg and Henderson, *Am. Jour. Phys.*, 1907, xviii, 113.  
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Ruedel, *Arch. f. exp. Path. u. Pharm.*, 1894, xxxiii, 79.  
Dubois and Stolte, *Jahrb. Kinderh.*, 1913, xxxiii, 21.  
Nelson and Williams, *Jour. Biol. Chem.*, 1917, xxviii, 231.

animals (rabbits), so that very large doses of acid, for instance, had to be given to obtain effects marked enough to study analytically. Repeated doses of 75 c.c., .9 per cent. HCl given to the rabbits of 1.5 kg. is very considerable and in the experiments of Fitz, Alsberg and Henderson usually finally resulted in death of the animal. Under such conditions, secondary results due to the large amount of acid must have complicated the picture.

This paper is an attempt to formulate the relation of acid base equilibrium to the urinary and fecal Ca and P excretion in normal adult man on a uniform mixed diet in which the greater portion of P and Ca are given in an easily available form. Three experiments were done on the effect of administration of HCl and NaHCO<sub>3</sub>, the one recorded here showing the effect of base and acid successively on the same diet. Previous to the days recorded in the tables, the subject had been on the diet for four days. The assumption is made that he was in calcium and phosphorus equilibrium, which is verified by the totals shown in the second table. The experiment was divided into three periods; normal, basic and acid. The P<sub>H</sub> of the urine in the normal period was 5.7 to 5.9 and the effect of administration of base and acid is seen clearly. The acidity (titrated according to Folin) runs parallel to this. The ammonia nitrogen shows clearly the well known effect of acid and base administration. The urinary P and Ca are progressively diminished by the NaHCO<sub>3</sub> and progressively increased by the acid.

Now on turning to the second table, which gives figures for urine and feces for periods constituting the last three days of the periods as given in the first table, we find that the total Ca and total P excreted in each period is constant. It is hardly to be expected that either loss or storage should occur under these conditions, sufficient to be discernible in a three day period. A dose of acid comparable to 75 c.c. of .9 per cent. HCl for a rabbit would undoubtedly produce a negative Ca balance. It may be noted that the CO<sub>2</sub> combining power of the blood during the entire experiment remained within the range of normal. In the alkaline period it rose to 77.7 and in the acid period went down to 69. Normal was 74.

The very close agreement in total Ca and P between periods in this experiment is accidental, the other experiments showing a somewhat greater variation. It is seen that in the second period, while the total P and Ca is the same as in period I, its distribution between urine and feces is changed. In the normal period, 57 per cent. of P and 28.7 per cent. of Ca are found in the urine, while in the alkaline period, these figures are 44 per cent. and 22 per cent. respectively. The acid period shows a reversal of this change, more Ca and P appearing in the urine.

Considering the fact that as high as 70 per cent. of the ash of feces is made up of Ca and P it seems quite plausible that an equilibrium condition should exist between the calcium phosphates in the intestine and the Ca and P of the blood and tissues which is influenced by the relative amounts of acid and base being metabolized. That Ca and P, with regard to absorption of re-excretion in the intestine, play a role entirely different from the other mineral elements is apparent from analyses of intestinal contents at various stages of digestion and the feces.<sup>2</sup>

Fitz, Alsberg and Henderson assumed that the increased phosphate in the urine after acid administration came from the tissues. This undoubtedly is true with extreme acidosis, but the data here recorded seem to show that urinary Ca and P can be increased at the expense of the fecal Ca and P, without loss to the body, if the acidosis is mild. A moderate dose of  $\text{NaHCO}_3$  may produce the reverse effect, without storage of Ca or P, in the body.

Besides the general biochemical significance which these data have, their application to nutritional studies and such problems as rickets should not be overlooked. The Ca and P excreted in the feces may be considered not available to the tissues and since the relative amount of acid and base in the diet influences the loss of Ca and P in the feces, the same level of intake may have a different nutritional significance, depending on the acid base equilibrium. The latter may be influenced not only by preponderance of acid or base forming elements in the food, but also by metabolic acidosis or alkalosis or possibly even by the intestinal bacterial flora.

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<sup>2</sup> For data see Schmidt and Strassburger, "Die Fäces des Menschen," or Schreuer in Oppenheimer's Handbuch, Band III, 2.

Further experiments are in progress to determine the limits of acid and base administration, in which the above observations hold, and to extend the study to various levels of Ca and P intake.

TABLE I.

Period.	Date Nov.	Vol. c.c.	D.	Ph.	NH <sub>3</sub> gm.	Acidity c.c. N/10	P gm.	Ca gm.
I. Normal. . . . .	14	960	1.020	5.8	1.42	726	2.06	.394
	15	1620	1.021	5.9	.91	748	1.66	.376
	16	1320	1.023	5.7	1.20	815	1.99	.455
	17	1225	1.025	5.8	1.20	760	1.71	.446
II. 15 gm. NaHCO <sub>3</sub> .	18	1950	1.019	6.5	.52	400	1.79	.389
	19	1850	1.021	7.2	.28	120	1.32	.307
	20	1700	1.022	7.3	.21	160	1.41	.297
III. 300 c.c. N/10HCl	21	1480	1.024	5.7	.61	508	1.68	.385
	22	1075	1.027	5.3	1.09	800	1.84	.467
	23	1250	1.023	4.9	1.44	850	1.86	.435
	24	1320	1.022	4.9	1.65	787	1.90	.512

TABLE II.

3 Last Days of Period.	P in Urine.	P in Feces.	Total P.	Per Cent. in Urine.	Ca in Urine.	Ca in Feces.	Total Ca.	Per Cent. in Urine.
I. Normal. . . . .	5.36	3.99	9.35	57	1.27	3.17	4.44	28.7
II. 15 gm. NaHCO <sub>3</sub> . . .	4.52	4.72	9.24	44	.99	3.42	4.41	22.2
III. 300 c.c. N/10 HCl. .	5.60	3.53	9.13	61	1.41	2.94	4.35	32.4

139 (1721)

### Studies on experimental rickets, IV.

**Cod liver oil as contrasted with butter fat in the protection against the effects of insufficient calcium in the diet.**

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In our experimental work we have made observations which demonstrate in a striking way the differences in the effectiveness