DISTRIBUTION OF THE PHOSPHORUS COMPOUNDS AND CALCIUM IN THE BLOOD OF CHILDREN*

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PART I.—NORMAL CHILDREN.

During the past 15 or 20 years our knowledge of the phosphorus content of the human blood has been considerably advanced by the work of several investigators. The inorganic phosphorus fraction, which is only about one-tenth of the total phosphorus content of the whole blood, appears to have claimed the attention of most of the previous workers, and, therefore, abundant data are available from the literature both for health and disease. Because of this, the inorganic phosphorus of the blood has already acquired some definite practical clinical value. The other compounds of phosphorus in the blood have attracted, however, the attention of fewer workers. The results of the present investigations are published in the hope of throwing further light on the distribution of phosphorus in the blood of the child, and especially on the quantitative changes resulting from disease.

Methods.—1. The method used for all the estimations of phosphorus compounds was, with one or two slight modifications, that adopted by Kay and Byrom¹.

2. Determinations of the calcium content of the blood serum were made according to the method described by Kramer and Tisdall².

While in studies of this nature it is probably desirable to obtain all the samples of blood in the morning after a whole night's fasting, it proved impracticable in every case to adhere to such a rule. At least 4 hours were allowed to elapse after a meal before the sample of blood was taken for analysis. This interval is probably long enough to exclude any direct influence of the meal on the partition of blood phosphorus. Venous blood was used with a minute quantity of potassium oxalate as anti-coagulant.

As very little is known at present regarding the equilibrium existing between the various forms of the phosphorus in the plasma and in the red blood corpuscles, or the ease with which an exchange may take place between the corpuscles and the plasma, the analytical procedures were commenced immediately the samples of blood were obtained.

Kay and Byrom¹ used the substance 'Heparin' as the anti-coagulant in the samples of blood for the hæmatocrit values, and potassium oxalate in that for the estimations of phosphorus compounds. In this study potassium oxalate was invariably used. It is true that the osmotic pressure of potassium oxalate is relatively high, and, as Rossdale³ pointed out, the addition of oxalate reduces the corpuscular volume per 100 c.cm. of blood. But, as oxalate is also used in the separation of plasma from the cells for the estimation of the phosphorus compounds, there is

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the advantage of comparing plasma volume and phosphorus content on samples prepared by the same method, whereas Kay and Byrom used 'Heparin' for the samples of blood used for the hæmatocrit readings and oxalate for those used for the analysis.

Results.—The results of direct analysis of the whole blood and the plasma for the phosphorus compounds, with the calculated results from these for the red blood corpuscles, of 10 normal children are given in Table 1 (pp. 202-3).

Discussion.

Hæmatocrit findings.—The average corpuscular volume of blood in 10 children was found to be 33.15 per cent., the highest being 38.8 per cent., and the lowest 28.7 per cent., of the whole blood. McKellips⁴ and his co-workers reported an average of 44.3 per cent. for children, and Kay and Byrom¹ gave an average of 43 per cent. for adults, but the latter noted the same range of fluctuation between the individual cases as reported for the cases of this paper.

Inorganic or free phosphorus.—The average free phosphorus in 10 normal children was found to be 4.15 mgrm. per cent. of the whole blood, 3.93 mgrm. per cent. of the blood plasma, and 4.63 mgrm. per cent. of the red blood corpuscles, showing that the corpuscles are richer in free phosphorus than the plasma. Our average value for the blood agrees with the findings of Hess and Gutman⁵, and Riesenfeld and his co-workers⁶, while Zucker and Gutman⁷, and Anderson⁸ reported slightly higher values. On the other hand, Jones and Nye⁹ reported an average value of 3.1 mgrm. per cent., Taylor and Miller¹⁰ found no inorganic phosphates present in the serum; and Buell¹¹ failed to find inorganic phosphates in the red blood corpuscles both of the dog and the human subject.

Ester phosphorus compounds.—The average ester phosphorus of 10 normal children was 22.4 mgrm. per cent. of the blood, 0.38 mgrm. per cent. of the blood plasma, and 67.25 mgrm. per cent. of the red blood corpuscles. These findings fully confirm the results of other workers that the blood plasma contains only a negligible quantity of the ester phosphorus, and that practically all the ester phosphorus is held by the corpuscles. Kay and Byrom termed the amount of the ester phosphorus per cent. of the red blood corpuscles the 'phosphoric index' of the blood, and they held that it was very constant in the normal adult. According to their findings, it had practically the same value of 53, rarely varying more than 10 per cent. on each side of the mean. Our results yield the 'phosphoric index' of 67.25 with a variation of about 20 per cent. in either direction of the mean value. This difference in the 'phosphoric index' would suggest that the red blood corpuscles of children are richer in the ester phosphorus compounds than those of adults.

Lipin phosphorus compounds.—The average lipin phosphorus was 13.74 mgrm. per cent. of the blood, 9.06 mgrm. per cent. of the blood plasma, and 23.26 mgrm. per cent. of the red blood corpuscles. Jones and Nye found, as calculated from their results given in terms of H_3PO_4 , 9.3 mgrm. per cent. for the blood plasma, and 19 mgrm. per cent. for the corpuscles. McKellips and his co-workers reported 17 mgrm. per cent. for the red blood corpuscles

for children. Bloor¹², and Kay and Byrom reported 18.7 mgrm. per cent. and 18 mgrm. per cent. for the corpuscles of adults respectively.

It has not been sufficiently emphasized that the lipin phosphorus compounds of the corpuscles in normal children, though nearly three times less in amount than the ester phosphorus, appear equally constant.

Calcium content of the blood serum.—The average calcium content of the blood serum of 9 normal children was found to be 10.73 mgrm. per cent. the highest figure being 11.1, and the lowest 10.08.

There appears to exist no evident relationship in distribution between the calcium of the serum and any phosphorus compound in either whole blood, blood plasma or corpuscles from these results.

Summary.

(1) The blood of normal children is relatively richer in all the phosphorus compounds than that of adults, and the phosphorus compounds in the blood of children tend to show slightly greater variations in distribution than those of adults.

(2) The red blood corpuscles contain more free phosphorus per cent. than the plasma.

(3) The 'phosphoric index' of the blood shows a tendency to be higher, but slightly less constant, in children than in adults.

(4) The lipin phosphorus of the red blood corpuscles is almost as constant an ingredient as is the ester phosphorus.

(5) The hæmatocrit value of the blood in children is lower than in adults.

(6) The average calcium content of blood serum is 10.73 mgrm. per cent.

PART II—NEPHRITIS.

In all investigations of this nature the initial stumbling block is the clinical classification of the types of nephritis. A simple separation into (a) acute, (b) subacute, and (c) chronic groups has been adopted here. The acute group includes all the cases suffering from the first attack of nephritis from which apparent recovery usually follows within two months. The subacute form comprises all the cases with the primary attack of nephritis of more prolonged duration, in which the disease has lasted for a period of some months. The chronic group consists of all the cases of nephritis in which the attack is either prolonged into years or in which there have been recurrent attacks of the same condition.

As early as 1915 Greenwald¹ showed that in many cases of nephritis the acid-soluble phosphorus of human blood serum was markedly increased, together with great variations in the lipid phosphorus content. Since then the researches of Marriott and Howland², Bloor³, Epstein and Rothschild⁴, Denis and Minot⁵, Denis and Hobson⁶, Briggs⁷, de Wesselow⁸, Hiller and his co-workers⁹, Daniels¹⁰, and Byrom and Kay¹¹ have added considerably to the elucidation and interpretation of the changes in the partition of phosphorus compounds of the blood in renal

diseases. Of all the previous workers Byrom and Kay were the first to study the simultaneous behaviour of all the phosphorus compounds of the blood in renal diseases. Further, all the workers studied these changes in the blood of adult patients.

Here an attempt has been made to study the changes in the partition of phosphorus compounds of the blood in 10 nephritic children, 8 of whom were in the acute stage, one in the subacute, and one in the chronic stage. In 5 of the 8 patients, who were suffering from acute nephritis, an endeavour was made to study the behaviour of phosphorus compounds of the blood during the whole course of the disease so that the samples of blood were submitted to complete analysis at different stages of the disease. In the remaining cases the analysis of blood was carried out only on one occasion. The results are given in Table 2 (pp. 202-3).

Discussion.

Inorganic or free phosphorus.—The findings for the free phosphorus of blood in 10 nephritic children correspond to a large extent with those of the other workers. In all the cases there was a tendency for the free phosphorus of blood to rise above the level of normal average during the disease except in Case 2. This child was suffering from acute nephritis with definite symptoms of uræmia, and the free phosphorus never rose above the normal level.

In most of the cases the rise in the free phosphorus and the retention of non-protein nitrogen occurred simultaneously, but this was not invariable as Cases 2 and 3 testify. No satisfactory explanation has been offered for these differences, and, in all probability, more than one factor is responsible.

(1) It might be the result not so much of the variation in the excretion as of the variation in the diet, and in the demand for phosphorus and nitrogen for anabolic purposes.

(2) There might be different mechanisms in the kidney for the excretion of waste products, namely, phosphates and urea, and these mechanisms might be, but need not be, impaired or damaged at the same time.

(3) Non-protein nitrogen retention in the blood might be due to the damage of the kidney, and the rise in free phosphorus of the blood might be due to the impairment of the regulating mechanism for the synthesis of the phosphorus compounds in the blood.

De Wesselow pointed out that the inorganic phosphate retention was apparently more definitely connected with the symptoms of uræmia than was the non-protein nitrogen retention, but neither of our two cases of acute nephritis with symptoms of uræmia lend support to his statement. He also suggested that the phosphoric retention involved certain deleterious results which the findings of our two cases did not support, because both of them exhibited marked symptoms of uræmia before there was any rise in the free phosphorus of blood. Further, Greenwald¹² studied the supposed toxicity of sodium phosphate, and he concluded that there was no evidence of direct toxic action of the phosphorus ions.

It can be readily seen from the Chart I that the rise of free phosphorus of the blood was highest during the acute stage of the disease, and it showed a tendency to taper off gradually as the condition improved. The free

phosphorus curve could be fairly well correlated with the clinical condition of patients, but it takes longer to come down to the normal level than the clinical signs and symptoms, for at the time of discharge from hospital, when the patients were considered completely cured clinically, it was still slightly above the normal level. Later the estimations of the blood were repeated, and the free phosphorus was found within the limits of normality.

In normal blood the free phosphorus was invariably found greater in amount per cent. in the corpuscles than in the blood plasma, but in the blood of nephritic children the free phosphorus was often disturbed, and its concentration was higher in the blood plasma.

Ester phosphorus compounds.—In all the five cases of acute nephritis studied during the whole course of the disease the ester phosphorus content of the whole blood was slightly diminished in amount per cent., which diminution was due not so much to the impoverishment of the red blood

CHART I.

Free phosphorus of blood in cases of nephritis during the disease.

corpuscles, which contain the bulk of the ester phosphorus compounds, as to the relative decrease in the portion of the red blood corpuscles per 100 c.cm. of whole blood.

The ester phosphorus of blood plasma, though normally very small in amount per cent., was, nevertheless, often found greatly increased during the course of disease, in one case reaching a value of 2.17 mgrm. per cent., i.e., more than five times the normal average value. Our findings agreed with those of Byrom and Kay who gave an average value of 0.5 mgrm. of the ester phosphorus per 100 c.cm. of blood plasma.

The average ester phosphorus of the red blood corpuscles, or the so-called phosphoric index of blood, for the 5 cases of acute nephritis was found to be 67.51 mgrm. per cent. which was within the limits of normality. This average figure would tend to negative any suggestion that there was an accumulation of the ester phosphorus content in the corpuscles during the disease; but, on closer examination of the figures, in 4 out of 5 cases the ester phosphorus

content of the corpuscles showed a tendency to be appreciably increased in amount per cent. at the onset of disease, the actual figures for the 4 cases being 72.7, 90.4, 83.7 and 74.0 mgrm. per cent. respectively.

The findings in the individual cases suggested that the regulating mechanism of the ester phosphorus of red blood corpuscles in nephritis was altered, for, at certain stages of the disease, the corpuscles seemed to be called upon to accommodate a greater amount of the ester phosphorus compounds per cell-unit, while at other stages they were called upon to release these compounds at a quicker rate.

Lipin phosphorus compounds.—The lipin phosphorus compounds of whole blood were found to be relatively slightly diminished in amount per cent. at the commencement of acute nephritis. They showed a tendency to rise appreciably, only to fall again during the course of disease, but they regained the limits of normality at the end of complete recovery. Thus in Case 1 the lipin phosphorus content of blood was 12.82 at the onset of disease, then rose

CHART II.

Lipin phosphorus of the blood during the course of acute nephritis in two patients.

gradually to 14.1 only to fall again to 10.88 mgrm. per cent. during the course of the illness: on complete recovery the lipin phosphorus rose again to 13.8 mgrm. per cent. These changes are well illustrated by Chart II.

The lipin phosphorus content of blood plasma in the individual cases showed a tendency to fluctuate during the acute stage of nephritis, and in 2 out of 5 cases the percentage content was very low. For instance, in Case 1 the percentage content varied from 5.1 to 10.2 mgrm. during the course of the illness.

The lipin phosphorus compounds of the red blood corpuscles showed a very marked tendency to fluctuate in amount per cent. during the illness. Thus in Case 1 the lipin phosphorus content of corpuscles fluctuated between 15.5 and 31.7 mgrm. per cent. at different stages of nephritis.

Our results for the lipin phosphorus of blood in acute nephritis fall partially into line with those published by Byrom and Kay, who found that the alcohol-ether soluble phosphorus of the blood was, on the average, diminished slightly

in amount per cent. in acute nephritis, increased slightly in subacute, and almost normal in chronic nephritis. On the other hand, they maintained that, in the majority of cases, the alcohol-ether soluble phosphorus of the blood plasma was above the normal value while that of the corpuscles remained constant or nearly so.

Further, the findings lead to the belief that there was an inter-relation between the lipin and ester phosphorus compounds of the red blood corpuscles. Their percentage increases or decreases tended to run parallel as can be seen from Chart III.

CHART III.

Showing simultaneous rise or fall in the lipin and ester phosphorus of red blood corpuscles in five cases of acute nephritis.

Total phosphorus content.—The average total phosphorus content of the whole blood of 19 estimations in nephritis was found to be 37.75 mgrm. per cent. This amount is 5.8 per cent. below the normal average.

The total phosphorus content of the blood in individual cases studied at different stages of the disease showed a tendency to vary in amount per cent. Thus in Case 1 it varied from 35.12 to 40.5 mgrm. per cent. The total phosphorus content of the blood depends for its amount on (a) the relative proportion between the red blood corpuscles and the plasma, (b) the total phosphorus content of the plasma portion, and (c) the total phosphorus content of the red blood corpuscles portion.

The average total phosphorus content of the blood plasma was 13.89 mgrm. per cent., i.e., 5.8 per cent. above the normal average. In the individual cases, however, it was found to vary considerably in amount per cent. during the disease. It showed a tendency to be lowest at the commencement of the disease, then rose appreciably during the disease, and returned to the limits of normality on complete recovery of the patient. These changes were especially marked in Cases 1 and 2.

The average total phosphorus content of the red blood cells was calculated to be 92.8 mgrm. per 100 c.cm., i.e., 2.4 per cent. below the normal average. In the individual cases of acute nephritis, however, the total phosphorus content was found very much increased in amount per cent. of the corpuscles

CHART IV.

Relationship between the lipin phosphorus of plasma and calcium of blood serum in nephritis.

at the onset of the illness, then it decreased with marked fluctuation during the disease, and, on recovery, it returned to within the limits of normality.

Calcium content of the blood serum in nephritis.—Marriott and Howland², Halversan and his co-workers¹³, de Wesselow⁸, Briggs⁷, and Schmitz and his co-workers¹⁴ reported, in turn, that the calcium content of blood serum in nephritis was often diminished in amount per cent.

Determination of the calcium content in 20 different samples of blood serum from nephritic children was carried out; and there was a slight tendency for the calcium to decrease in amount per cent., the lowest value recorded being 8.07 mgrm. per cent.

In the individual cases in which the calcium of blood serum was determined on several occasions during the course of the disease, no apparent

relationship between the free phosphorus of plasma and calcium content of the blood serum could be elicited. Binger¹⁵ and Tisdall¹⁶ reported a fall in calcium concentration of blood serum following the injection of phosphoric acid and its salts, but neither of them assigned this reduction in calcium to the accumulation of the inorganic phosphates in the blood serum.

On the other hand, the results showed some evidence in support of a relationship existing between the lipin phosphorus content of the blood plasma and the calcium content of blood serum in nephritis, which can be seen from Chart IV. This inter-relation was even more evident in the individual cases in which both the lipin phosphorus and calcium content were done simultaneously on several occasions during the disease. Both the lipin phosphorus and calcium either increased or decreased in amount per cent. at the same time and proportionately, i.e., the smaller the amount of one the smaller the amount of the other and vice versa, which can be seen from Chart V. The ratio, however, appeared to be different for each individual case.

CHART V.

Relationship between lipin phosphorus of plasma and calcium of serum in two cases of acute nephritis.

Summary.

(1) The free phosphorus of the blood in nephritis tended to rise above the normal level during the disease, and returned to the normal limits on recovery. The proportionate relationship between the free phosphorus of plasma and the red blood corpuscles was often disturbed during the disease.

(2) The increase in the free phosphorus and in the non-protein nitrogen of the blood frequently, but not invariably, occurred simultaneously.

(3) The percentage content of ester phosphorus of the blood showed a tendency to decrease.

(4) The percentage content of ester phosphorus of the blood plasma showed a tendency to increase.

(5) The ester phosphorus of the red blood corpuscles, or the so-called phosphorus index of blood, in nephritis showed much greater variation than in the normal. It was very high at the onset of nephritis.

(6) The percentage content of the lipin phosphorus of the blood, red blood corpuscles, and plasma showed appreciable variation during the disease.

(7) There was evidence of a relationship between the lipin and ester phosphorus compounds of the red blood corpuscles. Both of them showed a tendency either to fall or rise at the same time.

(8) The percentage content of the calcium of blood serum showed a tendency to be slightly diminished.

(9) There was evidence of a definite relationship between the lipin phosphorus of the blood plasma and the calcium content of the serum in nephritis.

PART III—DIABETES MELLITUS.

It seems clear that the phosphorus compounds of the blood are intimately associated with the metabolism of carbohydrates. Thus, it is well known that the concentration of the inorganic phosphates falls appreciably after a meal, and remains below the fasting level for several hours.

Wigglesworth and his co-workers¹ showed that the injections of insulin caused in rabbits a rapid fall in the inorganic phosphates of the blood, and Bollinger and Hartman² found that the fall was accompanied by a parallel diminution in the excretion of the inorganic phosphates in the urine. Harrop and Benedict³ similarly found that, after administration of insulin and glucose, there was a decrease in the inorganic phosphates of blood; an increase in the inorganic phosphates of muscle, and a diminished excretion of the inorganic phosphates in the urine.

Bloor⁴, and later Byrom⁵ showed that the lipoids of the blood were markedly increased in severe diabetes mellitus but normal in the milder types. Friedlander and Rosenthal⁶ reported that the intravenous injection of alkaline sodium phosphate caused in the diabetic a fall in the glucose concentration of the blood lasting for several hours while no change was observed in the percentage content of blood glucose in normal controls under the same conditions. They inferred from these observations that, as the respiratory quotient remained unaltered, synthesis of hexose-phosphate had occurred somewhere in the body.

The present study was undertaken to throw light on the distribution and partition of the phosphorus compounds and calcium of the blood in diabetes mellitus. The subjects of the study were four diabetic children (J. L. aged 5 years, J. B. 10 years, J. McK. 8 years, and A. G. 10 years). In three of the patients an attempt was made to determine the effect of treatment on the phosphorus content and distribution. Results are given in Table 3 (pp. 204-5).

Discussion.

Inorganic or free phosphorus.—The average of free phosphorus of the whole blood in 11 estimations of 4 diabetic children was found to be 15 per cent. below the normal average value. Only in 2 out of 11 estimations did the free phosphorus reach the normal level, and both these observations were made on

the same subject during the period in which the condition was well controlled by diet and insulin.

In 2 out of 3 cases the free phosphorus of the whole blood gradually rose towards the normal level as the metabolic disturbance was righted by means of careful dieting and insulin therapy. This distinct fall in the free phosphorus of the whole blood in diabetic children is not in accord with the findings for adults published by Byrom, who reported that there was no change in the concentration of the free phosphorus of the blood in diabetic adults until coma supervened when the value rose considerably.

The average free phosphorus of the blood plasma, although appreciably less than normal, was found to be greater than the free phosphorus of the whole blood. This is the reverse of the normal relationship existing between the free phosphorus of the whole blood, and blood plasma.

CHART VI.

Free phosphorus of the blood plasma and red blood corpuscles in three cases of diabetes mellitus.

The free phosphorus of the red blood corpuscles showed the most marked change. The average value was only 3.44 mgrm. per cent., i.e., 25.7 per cent. below the normal average. The lowest value recorded was 1.9. This poverty of the corpuscles in the free phosphorus was very striking, because not only did it exist in comparison to that of the corpuscles of normal children, but also in relation to amount of the free phosphorus in the whole blood, and plasma of diabetic children as can be seen from Chart VI.

Ester phosphorus compounds.—The average ester phosphorus of the whole blood was found to be slightly below the average for normal children. In the individual cases it showed a tendency to fall slightly in percentage as the condition improved.

The average ester phosphorus of the red blood corpuscles or the so-called phosphoric index of the blood was found to be 61.3 mgrm. per cent., i.e., 8.8

mgram. per cent. below the normal average. This confirmed the results of Byrom, who found a definite fall in the ester phosphorus of the corpuscles in diabetic patients being most marked in the coma stage when it was less than half of the normal.

The diminution in the ester phosphorus of the corpuscles in diabetic patients has not been explained satisfactorily, and different factors may play a part in its causation :—

CHART VII.

Lipin phosphorus of the red blood corpuscles and blood plasma in three cases of diabetes mellitus.

(1) It might be accounted for by the polyuria of diabetes mellitus, by which means an excessive amount of the free phosphorus is excreted by the kidney as a waste product, the ester phosphorus of the corpuscles being drawn upon by the process of hydrolysis to meet the existing deficit. That an excessive urinary excretion of phosphorus does take place in diabetes is indicated by the work of Ford from this laboratory*. In diabetic coma, however, there is

*These results have not been yet published.

often scanty secretion of urine or even anuria, although Byrom reported very low figures for the ester phosphorus of the corpuscles in such a condition. Further, that the polyuria per se is not the cause of the low value is also indicated by the high values for corpuscle-ester-phosphorus in the polyuria of chronic nephritis and diabetes insipidus as reported by Byrom and Kay⁷.

(2) Acidosis has been suggested as a possible cause. Kay⁸ recorded a fall in the ester phosphorus content of the red blood corpuscles in severe acidosis produced in a normal subject by the ingestion of ammonium chloride. Martland⁹ found that lowering of the pH of the blood tended to increase the hydrolysis of the ester phosphorus while an increase of the pH favoured synthesis. In the present series of cases there was no clinical or biochemical evidence of acidosis.

(3) There has also to be considered the possibility that insulin is an important factor in the synthesis of the ester phosphorus of the corpuscles from the free phosphorus of the plasma. The present findings lend no support to this view, for in no case was there recorded any increase in amount of the ester phosphorus of red blood corpuscles after the institution of insulin treatment. On the contrary Case 3 showed a distinct fall in the ester phosphorus of corpuscles as the condition became controlled by diet and insulin.

Lipin phosphorus compounds.—The average lipin phosphorus of the whole blood was found to be 15 per cent. below normal. This fall in Case 2 is especially noteworthy as the blood from this patient was lipæmic on every occasion on which it was submitted to analysis. The fall was entirely at the expense of the cellular portion of the whole blood. During treatment the lipin phosphorus showed a tendency to return to normal limits.

The average lipin phosphorus of the red blood corpuscles was found to be 14.93 mgrm. per cent., i.e., 35.8 below the normal level. The lowest value recorded was 7.35 as can be seen from Chart VII. These results not only fail to confirm the findings of Bloor and Byrom, each of whom found independently that lipoids were increased in severe diabetes mellitus, and normal in mild cases, but they show a marked poverty of the red blood corpuscles in lipin phosphorus. The fact that in 3 out of our 4 cases the diabetic condition was of a mild character only emphasizes this difference.

Total phosphorus content.—The average total phosphorus of the blood was found to be 36.34 mgrm. per cent., and this is 9.3 per cent. below the normal. In individual cases there was an appreciable variation in amount of the total phosphorus on different occasions. Thus, the samples of blood in Case 3 were analysed on four different occasions during the disease, and the total phosphorus of the blood varied from 34.28 to 41.6 mgrm. per cent.

The average phosphorus content of the blood plasma was found to be slightly above the normal level, and this was accounted for by the fact that there was lipæmia in one of the cases throughout.

Calcium content of the blood serum.—The calcium content of blood serum in diabetic patients was found to be within the limits of normality. The lowest figure reported was 9.1 mgrm. per cent., and the highest was 12.3 mgrm. per cent. of the blood serum.

Summary.

(1) The free phosphorus of the blood in diabetes mellitus is reduced. The reduction is much more marked in the corpuscles than in the plasma, so much so that the plasma content exceeds that of the red blood corpuscles, a state of affairs which is the reverse of normal. The free phosphorus both in corpuscles and plasma rises as the diabetic condition improves under treatment.

(2) The ester phosphorus of the red blood corpuscles is slightly decreased in amount.

(3) The lipin phosphorus of the corpuscles is markedly diminished in amount. During treatment it showed a tendency to a gradual return to within normal limits.

(4) The total phosphorus content of the blood is slightly diminished in amount.

(5) The calcium content of the blood serum keeps within the normal limits.

PART IV—INFANTILE TETANY AND IDIOPATHIC CONVULSIONS.

The close association of tetany with rickets, and the fact that the metabolism of phosphorus is disturbed in both conditions suggested the advisability of investigating the distribution of the various phosphorus compounds in these conditions. Five patients with signs of active tetany and rickets were studied, together with two infants suffering idiopathic convulsions of infancy. The results are given in Table 4 (pp. 204-5).

Inorganic or free phosphorus.—Numerous investigations have been carried out on the inorganic or free phosphorus of the blood in infantile tetany (Howland and Marriott¹, Kramer and his co-workers², Hess and his co-workers³, Hoag⁴, Scott and Usher⁵, and Marples and Crump⁶), and the results indicated that in a certain number of cases the percentage content of free phosphorus is raised.

In 3 out of 5 cases of infantile tetany, reported in this paper, the free phosphorus of the whole blood, plasma, and the red blood corpuscles was found to be raised by 30-40 per cent. above the normal average value, and in the other two cases it was within the limits of normality.

The free phosphorus of the whole blood, plasma, and the corpuscles in 2 cases of idiopathic convulsions was also found to be markedly increased. In one case the value was 80 per cent. above the normal level. Young infants give rather higher values for free phosphorus than do older children, but, in this instance, the values were too high to be accounted for satisfactorily by the factor of age alone. There was nothing to suggest the possibility of defective renal efficiency and no other cause can be suggested for the condition.

Ester phosphorus compounds.—The ester phosphorus of the whole blood in 4 out of 5 cases of infantile tetany was decreased in amount by 2.5 to 12.5 per cent. It was also decreased in the 2 cases of idiopathic convulsions.

The ester phosphorus of the blood plasma, though very small in amount, in 3 cases of infantile tetany was below the normal average, and in the other 2 cases it was above the normal average. The ester phosphorus of the blood plasma in 2 cases of idiopathic convulsions showed a tendency to be above the normal average.

The ester phosphorus of the red blood corpuscles both in the infantile tetany cases and idiopathic convulsions cases was found to be within the normal limits.

Lipin phosphorus compounds.—The blood both of cases of infantile tetany and idiopathic convulsions showed a tendency to be 15 to 40 per cent. poorer in the lipin phosphorus than the blood of normal children.

The lipin phosphorus of the blood plasma in 4 out of 5 cases of infantile tetany and in both cases of idiopathic convulsions was found to be diminished in amount by 30 per cent.

The lipin phosphorus of the red blood corpuscles in 4 out of 5 cases of infantile tetany was below the normal average, whereas the lipin phosphorus of the corpuscles of the 2 cases of idiopathic convulsions was within the limits of normality.

Total phosphorus content.—The average total phosphorus content of the blood in cases of infantile tetany was found to be 36.23 mgrm. per cent., i.e., 9.6 per cent. below the normal level. The average total phosphorus of the blood in 2 cases of idiopathic convulsions was 13 per cent. below the normal level.

The average total phosphorus of the blood plasma both in infantile tetany and idiopathic convulsions was found to be slightly below the normal average.

The total phosphorus content of the red blood corpuscles in cases of infantile tetany was found to be below the normal average whereas within the limits of normality in cases of idiopathic convulsions.

Calcium content of the blood serum.—The calcium content of the blood serum in cases of infantile tetany was found markedly reduced in amount per cent. The highest value recorded was 8.1 mgrm. per cent. The values for all the other cases were below 6.0 mgrm. per cent.

Summary.

(1) The free phosphorus of the blood in 3 out of 5 cases of infantile tetany and both cases of idiopathic convulsions showed a tendency to rise above the normal level.

(2) The ester phosphorus of the blood in both conditions showed a tendency to diminish in amount. The ester phosphorus of the blood plasma was found to vary in amount in tetany, and to increase in convulsions.

(3) The lipin phosphorus of the blood, and blood plasma was diminished in amount in both conditions. The lipin phosphorus of the corpuscles diminished in amount in tetany, and remained normal in idiopathic convulsions.

(4) The total phosphorus content of the blood, and blood plasma was slightly decreased in both conditions.

The total phosphorus of the corpuscles was diminished in amount in tetany but it was within normal limits in idiopathic convulsions.

PART V—MISCELLANEOUS GROUP OF DISEASES.

Comparatively few data are available concerning the complete partition of the phosphorus compounds of the blood in pathological conditions other than those already mentioned above.

McGlusky¹, Roller², and Byron and Kay³ studied independently the partition of phosphorus compounds of the blood in certain diseases, and they reported, though inconclusive, variations.

In this paper are detailed the results concerning the partition of phosphorus compounds of the blood in a group of patients suffering from blood disease and a variety of other conditions (rickets, albuminuria, dwarfism and ununited fracture). The results are given in Table 5 (pp. 206-7).

Though the results for any particular disease are too scanty to warrant any definite conclusions yet they indicate some interesting changes in the deviations from the normal.

Inorganic or free phosphorus.—The free phosphorus of the blood was found to be within normal limits in secondary anæmia and lymphadenoma. In the other conditions it was either above or below the normal level. The relationship between the free phosphorus of the blood, plasma and the red blood corpuscles was found to be upset at the expense of the latter in purpura simplex, rickets, albuminuria and lymphadenoma.

Ester phosphorus compounds.—The ester phosphorus of the blood was below the normal level in all the conditions studied except ununited fracture and dwarfism where it was slightly above the normal average value.

The ester phosphorus of the red blood corpuscles was within the normal limits in purpura simplex, ununited fracture, rickets, and dwarfism. It was below the normal in albuminuria and lymphadenoma, but 17.0 per cent. above the normal in secondary anæmia. These findings for anæmia are in agreement with the findings of Byrom and Kay, and also with what one might expect if there were an increased proportion of the young cells in blood whose ester phosphorus content is generally admitted to be slightly greater than in the normal.

Lipin phosphorus compounds.—The lipin phosphorus of the blood was invariably diminished to some extent in all the conditions.

The lipin phosphorus of the blood plasma showed a tendency to decrease in amount in all the conditions except albuminuria where it was actually above the normal.

The lipin phosphorus of the red blood corpuscles showed a marked tendency to fall in amount in all the conditions except ununited fracture, where it was found markedly increased. In the case of albuminuria the lipin phosphorus of the corpuscles was less than half of the normal average.

The lipin phosphorus of the corpuscles in secondary anæmia was found to be about 30.0 per cent. below the normal. Bloor and Macpherson⁴ found that the lipid composition of the corpuscles in anæmia was normal in almost all the cases. Further, Bloor⁵ studied rabbits in which lipæmia was produced by the acute experimental anæmia through hæmorrhage, and he showed that of all the phosphoric acid compounds of the blood the lipid phosphorus was most markedly affected by the anæmia and subsequent lipæmia. Values up

to 5 times the normal were found in the blood plasma, and 2 or more times the normal in the corpuscles. He concluded that the only phosphorus compound which was notably higher in the newly formed red blood corpuscles than in the older ones was the lipid phosphorus. The results for the lipin phosphorus of our cases of secondary anæmia showed a definite tendency to be slightly diminished in the blood plasma, and markedly so in the red blood corpuscles. This difference might be due to the fact that his results were obtained from rabbits after an experimental anæmia followed by lipæmia, whereas our results were obtained from the blood of patients suffering from secondary anæmia with no evidence of lipæmia.

Byrom and Kay³ showed that in individual cases of secondary anæmia the phosphorus partition varied, but the average figures indicated that, on the whole, the changes were due merely to alteration in the relative proportion of the corpuscles to the plasma in blood, and were not due to any quantitative change in the nature of their phosphorus compounds. As they appear to have estimated only the phosphorus compounds of the 'whole' blood, it was very easy to arrive at somewhat deceptive conclusions. Thus, as the relative diminution of the cellular portion of the blood in secondary anæmia is seldom very marked, and as the blood plasma contains an appreciable amount of the lipin phosphorus, there cannot be expected more than a slight diminution in the lipin phosphorus per 100 c.cm. of the whole blood. If, however, this slight diminution is directly at the expense of the corpuscles, and the latter are relatively diminished, it is evident that the fall in the percentage of lipin phosphorus of the corpuscles will be much greater than that of the whole blood, and this our results confirm.

The effect of pituitary extract on the partition of phosphorus compounds of the blood in a case of dwarfism.—This case was a girl aged 9½ years, who had stopped growing normally at the age of 5 years. Her actual height was 102·5 cm., the normal for her age being 128·5 cm. Her actual weight was 16·92 kgrm., and the expected weight for her age is 27·5 kgrm. The condition was diagnosed as one of pituitary dwarfism.

A sample of her blood having been analysed for the phosphorus compounds, she was given pituitary extract for two months, at the end of which the blood was re-analysed, the results compared, and the difference between the two worked out in percentages. The results are given in Table 6 (pp. 206-7).

PART VI—GENERAL DISCUSSION OF RESULTS.

One of the most significant observations forcing itself into prominence from all the present investigations on phosphorus partition of the blood in disease, is that the phosphorus compounds of the blood in disease show a tendency to suffer a redistribution. These changes in distribution vary greatly in different diseases. In no disease was there found any tendency for an increase of total phosphorus content of the blood above the normal average value. In the individual phosphorus compounds of the blood, blood plasma, and red blood corpuscles, there were changes in either direction, i.e.,

either increased or decreased. Of the free, ester, and lipin phosphorus fractions the ester phosphorus showed the greatest stability. In healthy children, it was shown that the ester phosphorus, as well as lipin phosphorus, of the red blood corpuscles were constant ingredients, but in disease the ester phosphorus fraction suffered less change than the lipin phosphorus fraction which invariably and markedly did suffer per unit volume. Price-Jones⁶ demonstrated that in disease the red blood corpuscles were large, the average volume of a cell, according to Haden⁷, being 1.42 times greater than the normal average. Larger cells would indicate a smaller surface area per unit volume of cells, and a smaller total volume of the surface film with a relatively larger content of those constituents which do not occupy the surface. Thus, this would support the suggestion that the phosphoric esters were not on the surface of the cells but in the interior, which would be the opposite of the hæmoglobin as indicated by the experiments of Burker⁸, and Emmons⁹ who believed that the pigment was distributed superficially over the cells. Similarly Garter and Grendel¹⁰ stated that the surface of the red cells was covered by a layer of the lipin molecules which was two molecules thick, and it would follow from this that the smaller the surface of the red cells the fewer the lipin molecules per unit volume. If this were true both of the ester phosphorus fraction and the lipin molecules, it would not be idle to suggest that (a) the ester phosphorus fraction, being inside the cells, would be less likely to be affected, for, within limits, the fewer the cells the greater their size, and they could thus accommodate relatively greater amounts of the phosphoric esters; (b) the amount of lipin phosphorus fraction would depend directly upon the sum total of the surface of the cells; and (c) the lipin phosphorus, being lodged on the surface, might further account for its lability, for it would be more likely than not that, under stress of disease, the superficial layers of the red blood corpuscles would be the first to bear its brunt.

General conclusions.

(1) In all the diseases studied marked changes in the partition of the phosphorus compounds of the blood were noted.

(2) The changes which took place were not identical in all the diseases, but the most frequent and marked changes related to the free and lipin phosphorus fractions.

(3) In no disease was there noted any accumulation in the phosphorus content of the blood, but merely a redistribution of the different phosphorus compounds. There was, however, noticed a tendency for the total phosphorus content of the blood to fall in amount during disease.

In conclusion, it is a pleasant duty to acknowledge my gratitude to Prof. Leonard Findlay for his criticism throughout. Further, I am greatly indebted to Dr. N. Morris for his invaluable advice in matters of biochemical analysis, constant encouragement, and assistance to select suitable cases for the study to Dr. S. B. Fleming for facilities for studying some of the cases; and to Dr. S. Graham for estimating the non-protein nitrogen of blood for me, and other assistance willingly given on innumerable occasions.

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(References concluded on p. 208)

EXPLANATION OF TABLES.

TABLES :—F.P.=Inorganic or free phosphorus; F.E.P.=Inorganic plus ester phosphorus; E.P.=Ester phosphorus; L.P.=lipin phosphorus; T.P.(C.) and (A.)= Total phosphorus by combustion and addition respectively; Ca=Calcium; N.P.N.=Non-protein-nitrogen.

TABLE
PHOSPHORUS COMPOUNDS OF THE BLOOD

Case No.	Age years	Diagnosis	Whole blood					
			F.P.	F.E.P.	E.P.	L.P.	T.P.(C.)	T.P.(A.)
1	8	Normal	3·89	23·58	20·69	13·7	36·7	37·28
2	12	Do.	4·4	29·2	24·8	13·9	43·24	43·1
3	11	Do.	4·1	31·4	27·3	12·9	45·1	44·3
4	11	Do.	4·6	30·3	26·7	14·1	43·3	44·4
5	8½	Do.	4·6	24·7	20·1	15·4	39·6	40·1
6	5	Do.	4·04	23·8	19·76	14·2	38·7	38·0
7	9	Do.	3·8	24·24	20·44	12·5	36·9	36·74
8	5½	Do.	4·11	25·5	21·39	12·7	38·5	38·3
9	12	Do.	3·9	24·3	20·4	14·8	39·9	39·1
10	4	Do.	4·11	26·6	22·49	13·2	40·1	39·8
Average	—	—	4·15	26·36	22·4	13·74	40·2	40·11
Highest	—	—	4·6	31·4	27·3	15·4	45·1	44·4
Lowest	—	—	3·8	23·58	19·76	12·5	36·7	36·74

TABLE
PHOSPHORUS COMPOUNDS OF THE BLOOD

Case No.	Age in years	Diagnosis	Whole blood					
			F.P.	F.E.P.	E.P.	L.P.	T.P.(C.)	T.P.(A.)
—	—	Normal average	4·15	26·36	22·4	13·74	40·2	40·11
1	11	Acute nephritis with uræmia	3·34	25·97	22·63	12·82	38·46	38·78
			6·94	26·6	19·66	13·7	38·5	40·3
			5·15	26·4	21·25	14·1	41·1	40·5
			4·48	24·24	19·76	10·88	35·8	35·12
			4·11	25·3	21·19	13·8	39·9	39·1
			—	—	—	—	—	—
2	6½	Acute nephritis with uræmia	3·11	25·64	22·53	12·25	38·2	37·89
			4·08	—	—	—	—	—
			4·06	26·2	22·14	13·62	38·65	39·82
			3·7	23·8	20·1	11·57	35·1	35·37
3	5½	Acute nephritis	5·2	26·1	20·9	9·0	34·8	35·1
			3·74	21·73	17·99	12·62	34·26	34·35
			5·1	24·2	19·1	12·07	35·84	36·27
			4·2	22·7	18·5	11·2	33·85	33·9
			3·83	23·5	19·67	12·9	35·9	36·4
4	6½	Acute nephritis	5·1	24·3	19·2	12·07	35·7	36·37
			4·71	24·5	19·79	11·4	35·84	35·9
			4·1	24·2	20·1	13·1	37·56	37·3
5	9½	Acute nephritis	5·8	26·1	20·3	13·28	39·87	39·38
			4·96	27·2	22·24	14·1	41·6	41·3
			4·1	26·8	22·7	13·5	40·49	40·3
6	8	Acute nephritis	4·96	26·3	21·34	13·18	40·79	40·1
7	3½	Acute nephritis	5·2	26·6	21·4	13·9	40·87	40·5
8	12¼	Acute nephritis	4·13	24·7	20·54	8·95	33·6	33·65
9	12	Chronic nephritis	4·5	27·21	22·71	10·3	37·23	37·51
10	11½	Subacute nephritis ...	4·5	26·6	22·1	13·9	40·16	40·5

1.

IN NORMAL CHILDREN. (mgrm. per cent.)

Plasma					Corpuscles				Hæma- tocrit R.B.C.%	Ca in serum	R.B.C. in millions
F.P.	F.E.P.	E.P.	L.P.	T.P.	F.P.	L.P.	E.P.	T.P.			
3·53	4·14	0·61	10·1	14·24	4·7	21·7	65·4	91·8	31·0	10·9	—
4·2	4·8	0·6	8·9	13·7	4·93	25·3	80·2	110·4	30·4	—	4·8
3·9	4·37	0·47	8·53	12·9	4·47	20·9	76·9	102·27	35·1	10·08	5·1
4·2	4·6	0·4	10·7	15·3	5·46	20·0	71·8	97·26	36·8	11·04	—
4·39	4·6	0·21	9·9	14·5	4·94	24·0	51·4	80·34	38·8	10·9	—
3·8	4·1	0·3	10·1	12·8	4·58	23·1	62·2	89·88	31·4	10·76	4·86
3·58	3·73	0·15	7·87	11·6	4·33	23·3	67·8	95·43	30·0	11·0	4·4
4·01	4·33	0·32	8·69	11·9	4·35	22·6	73·7	100·65	28·7	10·7	4·51
3·7	4·05	0·35	6·61	10·66	4·23	28·7	54·8	87·73	36·8	11·1	—
4·0	4·4	0·4	9·2	13·6	4·33	23·0	68·3	95·63	32·5	10·1	—
3·93	4·31	0·38	9·06	13·12	4·63	23·26	67·25	95·13	33·1	10·73	—
4·39	4·8	0·61	10·7	15·3	5·46	28·7	80·2	110·4	38·8	11·1	—
3·53	3·73	0·15	6·61	10·66	4·23	20·0	51·4	80·34	28·7	10·08	—

2.

IN NEPHRITIS. (mgrm. per 100 c.cm.)

Plasma					Corpuscles				Hæma- tocrit R.B.C.%	Ca in serum mgrm. %	Blood N.P.N. mgrm. %
F.P.	F.E.P.	E.P.	L.P.	T.P.	F.P.	L.P.	E.P.	T.P.			
3·93	4·31	0·38	9·06	13·12	4·63	23·26	67·25	95·13	33·15	10·73	—
3·13	5·3	2·17	5·1	10·4	3·8	31·7	72·7	108·2	29·0	9·72	32·1
6·94	7·5	0·6	9·54	17·04	6·95	21·7	56·3	85·0	34·2	10·9	54·5
4·9	5·5	0·6	10·2	15·7	5·7	23·65	71·8	101·2	29·0	11·1	57·1
4·59	5·0	0·41	8·57	13·16	4·25	15·5	58·3	78·05	33·4	10·7	—
4·4	4·76	0·36	9·64	13·4	3·5	23·9	61·8	89·2	33·9	10·9	33·3
3·68	4·07	0·39	8·65	12·72	3·2	23·29	90·4	116·89	24·6	—	84·4
—	—	—	—	—	—	—	—	—	—	—	—
3·95	4·58	0·63	11·72	16·3	4·4	19·6	90·2	114·2	24·0	—	34·0
3·69	4·1	0·41	9·78	13·88	3·74	17·1	81·4	102·24	24·3	—	—
4·98	5·5	0·52	6·99	12·5	5·87	15·1	83·7	104·67	24·5	9·04	39·1
3·77	4·03	0·26	9·12	13·15	3·7	20·0	55·1	78·8	32·3	10·9	—
5·38	6·15	0·77	8·06	14·08	4·4	22·3	65·7	92·4	28·2	9·76	—
4·34	4·7	0·36	7·7	12·4	3·9	18·7	57·4	80·0	31·8	9·56	—
3·89	4·2	0·31	8·5	12·7	3·69	22·8	63·6	90·1	30·6	10·2	—
4·56	5·08	0·52	8·22	13·3	6·66	23·46	74·0	104·12	25·6	10·08	62·3
4·59	4·8	0·21	7·68	12·66	4·96	19·3	61·7	85·96	31·8	9·6	—
3·92	4·35	0·43	8·9	13·15	4·58	24·07	71·4	100·05	27·7	—	44·4
5·73	6·05	0·32	8·41	14·46	5·9	22·2	57·0	85·1	35·2	9·84	43·5
4·8	5·42	0·62	9·28	14·7	5·28	23·59	64·39	93·26	33·9	9·3	31·6
3·93	4·4	0·43	9·27	13·67	4·5	22·0	67·9	94·4	33·0	10·7	30·1
4·73	4·99	0·26	9·16	14·15	5·33	20·0	57·0	82·33	37·1	9·26	—
5·0	5·4	0·4	10·1	15·5	5·8	23·0	72·0	100·8	29·3	8·8	71·8
3·55	3·78	0·23	6·02	9·8	5·1	14·2	56·9	76·2	35·8	8·07	—
4·28	4·64	0·36	10·05	14·69	4·9	10·7	63·8	79·4	35·2	9·86	—
4·4	5·03	0·63	12·27	17·3	4·7	17·8	74·4	96·9	29·1	9·6	—

TABLE
PHOSPHORUS COMPOUNDS OF THE
(mgrm. per

Case No.	Age in years	Diagnosis	Whole blood					
			F.P.	F.E.P.	E.P.	L.P.	T.P.(C.)	T.P.(A.)
—	—	Normal average	4·15	26·36	22·4	13·74	40·2	40·11
1	4	Diabetes mellitus	3·0	24·4	21·4	9·1	34·0	33·5
			3·3	27·4	24·1	8·9	37·6	36·3
			3·5	22·2	18·7	14·9	37·4	37·1
2	10	Diabetes mellitus	3·8	24·0	20·2	10·4	34·2	34·4
			3·17	25·3	22·13	14·8	39·75	40·1
			3·4	21·53	18·13	12·98	34·72	34·51
3	8	Diabetes mellitus	3·48	28·7	25·22	12·9	41·4	41·6
			3·49	25·83	22·34	11·26	37·45	37·09
			4·11	24·06	19·95	10·22	34·52	34·28
			4·2	26·7	22·5	12·36	39·3	39·06
4	10	Diabetes mellitus	3·54	23·46	19·92	8·4	32·05	31·86

TABLE
PHOSPHORUS COMPOUNDS OF THE BLOOD IN
(mgrm. per

Case No.	Age in years	Diagnosis	Whole Blood					
			F.P.	F.E.P.	E.P.	L.P.	T.P.(C.)	T.P.(A.)
		Normal average	4·15	26·36	22·4	13·74	40·2	40·11
1	1 ¹ / ₁₂	Infantile tetany	5·5	22·9	17·35	8·0	31·2	30·9
2	4 ¹ / ₈	Do.	3·5	23·4	19·9	10·4	33·4	33·8
3	1 ¹ / ₂	Do.	4·04	25·2	21·16	11·7	37·4	36·9
4	³ / ₈	Do.	5·74	27·1	21·36	10·4	36·7	37·5
5	1 ⁵ / ₁₂	Do.	6·1	33·4	27·3	9·26	42·73	42·66
		Average	4·97	26·4	21·41	9·95	36·28	36·23
7	4 weeks	Idiopathic convulsions ...	6·49	25·3	18·81	11·41	36·7	36·76
8	5 weeks	Do.	5·37	23·1	17·73	9·8	33·3	32·9

3.

BLOOD IN DIABETES MELLITUS.
100 c.cm.)

Plasma					Corpuscles				Hæma- tocrit R.B.C. %	Ca in serum mgrm. %
F.P.	F.E.P.	E.P.	L.P.	T.P.	F.P.	L.P.	E.P.	T.P.		
3·93	4·31	0·38	9·06	13·12	4·63	23·26	67·25	95·13	33·15	10·73
2·85	5·56	0·71	7·7	11·26	3·3	11·7	60·1	75·1	34·8	9·9
3·25	4·02	0·77	8·88	12·9	3·4	8·9	63·8	76·1	37·0	11·2
4·2	4·29	0·09	9·61	13·9	1·96	26·89	60·9	89·75	30·6	9·1
3·9	4·1	0·2	12·0	16·1	3·63	7·35	58·3	69·28	34·4	10·3
3·22	3·68	0·46	14·52	18·2	3·0	15·3	63·5	81·8	34·5	10·1
3·28	3·6	0·32	10·88	14·48	3·63	17·24	54·3	75·17	33·0	10·8
3·15	3·65	0·5	11·25	14·9	4·15	16·2	75·4	95·75	33·0	12·3
3·51	3·8	0·29	8·85	12·65	3·4	16·4	69·4	89·2	31·9	10·8
4·22	4·54	0·32	8·96	13·5	3·9	12·5	55·4	71·8	35·6	11·2
4·4	4·75	0·35	8·35	13·1	3·85	19·3	61·37	84·52	36·3	11·0
3·48	3·98	0·5	5·86	9·85	3·65	12·5	51·8	67·95	37·8	10·47

4.

INFANTILE TETANY AND IDIOPATHIC CONVULSIONS.
100 c.cm.)

Plasma					Corpuscles				Hæma- tocrit R.B.C. %	Ca in serum mgrm. %
F.P.	F.E.P.	E.P.	L.P.	T.P.	F.P.	L.P.	E.P.	T.P.		
3·93	4·31	0·38	9·06	13·12	4·63	23·26	67·25	95·13	33·15	10·73
5·4	5·53	0·13	4·06	9·59	5·9	18·2	61·6	85·7	28·0	8·1
3·22	3·36	0·14	6·39	9·75	4·15	19·4	64·2	87·75	30·8	5·2
3·89	4·5	0·61	6·0	10·5	4·34	23·0	62·1	89·44	33·4	5·3
5·2	5·45	0·25	9·47	14·92	7·1	12·7	74·9	94·7	28·4	4·8
6·17	6·58	0·41	6·48	12·65	6·0	13·7	70·3	90·0	38·5	5·2
4·75	5·08	0·3	6·48	11·48	5·5	17·4	66·6	89·52	31·8	5·72
5·79	6·25	0·46	7·35	13·6	8·5	23·3	72·7	104·5	25·4	—
5·3	5·9	0·6	5·18	11·08	5·5	21·8	62·2	89·5	27·8	—

TABLE
PHOSPHORUS COMPOUNDS OF THE
(mgrm. per

Case No.	Age in years	Diagnosis	Whole blood						
			F.P.	F.E.P.	E.P.	L.P.	T.P.(C.)	T.P.(A.)	
		Normal Average	4·15	26·36	22·4	13·74	40·2	40·11	
1	12	Secondary anæmia	4·52	23·5	18·98	10·01	33·6	33·51	
2	6 $\frac{1}{2}$	Do.	3·98	23·6	19·62	10·3	34·2	33·9	
3	8	Do.	4·1	25·3	21·2	11·2	36·17	36·5	
4	3 $\frac{1}{2}$	Purpura simplex	3·25	20·61	17·36	9·05	30·4	29·66	
5	6 $\frac{1}{2}$	Ununited fracture	6·1	29·2	23·1	13·2	43·8	42·4	
6	1 $\frac{5}{12}$	Rickets	3·21	23·84	20·63	12·07	36·43	35·91	
7	5 $\frac{1}{2}$	Albuminuria... ..	4·87	25·9	21·3	10·22	36·23	36·12	
8	8	Lymphadenoma	4·06	23·89	19·83	11·74	36·13	35·63	
9	9 $\frac{1}{2}$	Dwarfism	4·36	29·2	24·84	9·8	39·13	39·0	

TABLE
THE EFFECT OF PITUITARY EXTRACT ON THE PARTITION OF
(mgrm. per

						Whole blood				
						F.P.	F.E.P.	E.P.	L.P.	T.P.(C.) T.P.(A.)
Before treatment	...	...	...	...	...	4·36	29·2	24·84	9·8	39·13 39·0
Two months after treatment	...	...	...	...	...	3·98	23·6	19·62	10·3	34·2 33·9
Difference in percentage	...	...	...	...	...	—8·7%	—19%	—21%	+5·1%	—12·6% —13%

TABLES :—F.P.=Inorganic or free phosphorus ; F.E.P.=Free plus ester phosphorus ; E.P.=Ester respectively ; Ca=Calcium. N.P.N.=Non-protein-nitrogen.

5.

BLOOD IN MISCELLANEOUS DISEASES.
100 c.cm.)

Plasma					Corpuscles				Hæmo- toerit R.B.C. %	Ca in serum mgrm. %
F.P.	F.E.P.	E.P.	L.P.	T.P.	F.P.	L.P.	E.P.	T.P.		
3.93	4.31	0.38	9.06	13.12	4.63	23.26	67.25	95.13	33.15	10.73
4.3	4.45	0.15	8.15	12.6	5.2	16.5	81.3	103.0	23.2	10.8
3.8	4.1	0.3	8.4	12.5	4.6	16.1	79.5	100.2	24.4	10.9
3.8	4.2	0.4	9.1	13.1	4.87	16.6	74.9	96.37	27.9	9.12
3.32	3.7	0.38	7.2	10.52	3.07	13.7	60.3	77.1	28.3	11.06
5.13	8.2	3.07	5.4	13.6	7.9	28.1	61.1	97.1	34.5	11.1
3.32	3.52	0.2	8.55	12.07	2.9	19.6	64.6	87.1	31.7	8.14
5.57	6.06	0.49	9.81	15.87	3.6	10.9	57.8	71.6	36.3	—
4.2	4.56	0.36	6.08	10.69	3.79	22.6	57.1	83.49	34.3	9.8
4.03	4.7	0.67	7.76	12.46	5.0	13.9	73.4	92.3	33.2	9.91

6.

PHOSPHORUS COMPOUNDS OF THE BLOOD IN A CASE OF DWARFISM.
100 c.cm.)

Plasma					Corpuscles				Hæma- toerit R.B.C. %	Ca in serum mgrm. %
F.P.	F.E.P.	E.P.	L.P.	T.P.	F.P.	L.P.	E.P.	T.P.		
4.03	4.7	0.67	7.76	12.46	5.0	13.9	73.4	92.3	33.2	9.91
3.8	4.1	0.3	8.4	12.5	4.5	16.1	79.4	100.0	24.4	10.9
—5.7%	—12.8%	—55%	+8.2%	0	—10%	+15.8%	+8.1%	+8.3%	—26.5%	+10%

phosphorus; L.P.=Lipin phosphorus; T.P.(C.) and T.P.(A.)=Total phosphorus by combustion and addition

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