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Glycolysis in the Blood of the Goat.*

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A previous communication[6] reported that the normal blood sugar of the goat ranges from 24 to 65 mg. per 100 cc., levels considerably lower than those reported for other laboratory animals. A second difference between the blood of the goat and that of other animals is indicated by the data given below, namely, a difference in the behavior of the inorganic phosphate during glycolysis.

It has been repeatedly observed [2, 7, 10, 15] that the fall in blood sugar which occurs in shed blood is accompanied by typical changes in the level of the inorganic phosphate. During the first few hours of glycolysis, while the sugar is being destroyed rapidly, the inorganic phosphate decreases. When the sugar has practically all disappeared and glycolysis has, perforce, either stopped or slowed to a very low rate, there is a rapid and extensive increase in the level of the inorganic phosphate. These changes during glycolysis have been observed in the blood of the dog, the rabbit and the human.

Data are given below on the changes in sugar, lactic acid, and inorganic phosphate which occur in the blood of the goat, when defibrinated and incubated at body temperature. The blood of dogs was used for control purposes.

For these studies, 75 to 100 cc. of blood was drawn from the jugular vein and defibrinated with a glass rod. Samples were withdrawn immediately for the determination of sugar, lactic acid, and inorganic phosphate. The flask containing the remainder of the blood was stoppered and placed in the incubator at a temperature of 37° to 38°C. Aseptic precautions were not taken as it has been shown that slight bacterial contamination alters neither the glycolytic rate[8, 13] nor the course of the accompanying changes in the inor-

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[6] Cutler, J. T., *J. Biol. Chem.*, 1934, **106**, 653.

[2] Barrenschien, H. K., and Hübner, K., *Biochem. Z.*, 1930, **229**, 329.

[7] Engelhardt, W. A., and Braunstein, A. E., *Biochem. Z.*, 1928, **201**, 48.

[10] Guest, G. M., *J. Clin. Invest.*, 1932, **11**, 555.

[15] Roche, A., and Roche, J., *Bul. de la Soc. Chim. Biol.*, 1929, **11**, 549.

[8] Falcon-Lesses, M., *Arch. Int. Med.*, 1927, **39**, 412.

[13] Mackensie, G. M., *J. Exp. Med.*, 1915, **22**, 757.

ganic phosphate.[10] Samples were withdrawn for the determinations at intervals of 1 to 4 hours, and the experiments were continued for 12 to 24 hours.

The sugar was determined by Benedict's method,[4] the lactic acid by the method of Friedmann and Kendall,[9] and the inorganic phosphate by Briggs modification[5] of the method of Bell and Doisy.[3] All determinations were made on whole blood.

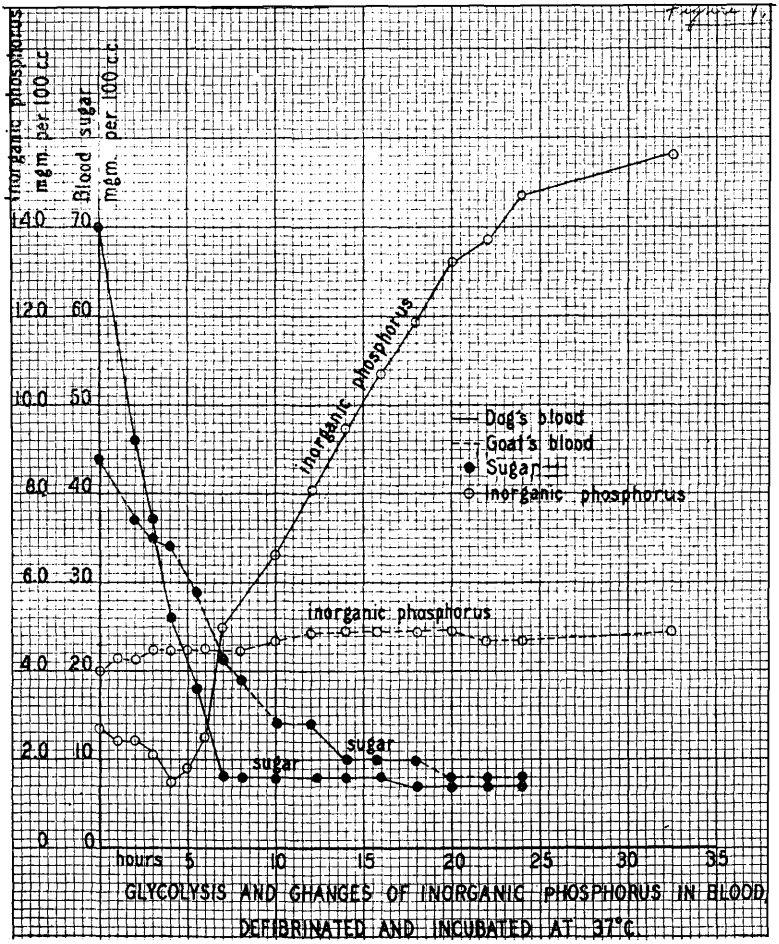

FIG. 1.

Glycolysis and accompanying changes in inorganic phosphate in blood of the dog and of the goat.

4 Benedict, S. R., *J. Biol. Chem.*, 1926, **68**, 759.

9 Friedmann, T. E., and Kendall, A. I., *J. Biol. Chem.*, 1929, **82**, 23.

5 Briggs, A. P., *J. Biol. Chem.*, 1922, **53**, 13.

3 Bell, R. D., and Doisy, E. A., *J. Biol. Chem.*, 1920, **44**, 55.

Sugar disappears progressively from the blood of the goat as it does from that of other animals. The glycolytic rate is, however, considerably slower in goat blood than in dog blood. In our experiments the rate of fall of sugar in the blood of goats varied from 2.2 mg. to 6.2 mg. per 100 cc. per hour, with an average of 4.1 mg., while in dog blood, the rates ranged from 7.0 mg. to 9.2 mg. per 100 cc. per hour, with an average of 8.1 mg. The normal course of glycolysis in the blood of either the goat or the dog may be noted in Fig. 1. The sugar falls progressively over a period of 6 to 14 hours after the blood is drawn until it reaches a level of 6 to 8 mg. per 100 cc., at which level it remains for as long as 48 hours. We believe that this residue is not glucose, but some other reducing substance.

As the glucose diminishes, lactic acid appears in the blood of the goat, as in that of other animals, in amounts equal to the sugar which disappears. The figures presented in Table I show that during the first 6 hours of glycolysis, the lactic acid formed and the sugar lost are equal, within the limits of error of the methods used. After 6 to 8 hours the lactic acid apparently begins to be destroyed, since it decreases in amount from this point. Except for the difference in rate, glycolysis in goat blood is like that in dog blood, in that the progressive loss of sugar can be accounted for by a simultaneous appearance of lactic acid. However, a suggestion of a divergence in the intermediate steps in the process in the blood of the 2 species is found in the behavior of the inorganic phosphate during glycolysis.

The changes in the level of the inorganic phosphate during glycolysis in dog blood in our experiments are like those reported by Roche and Roche[15] and those observed in the blood of rabbits and normal humans by Guest.[10] During the first 4 to 6 hours of incubation the concentration of the inorganic phosphate decreases. It then begins to increase rapidly and continues to do so for 10 to 20 hours. (Fig. 1.)

In goat blood these characteristic changes do not occur during glycolysis. (Fig. 1.) During 24 hours of incubation there is only a slow continuous rise in the level of the inorganic phosphate, which amounts to but 1 or 2 mg. per 100 cc. This rise bears no apparent relationship to glycolysis as it continues at approximately the same rate whether sugar is present or has all disappeared.

Further evidence of the usual relationship of inorganic phosphate to glycolysis is furnished by the observation, reported by

TABLE I.
Production of Lactic Acid During Glycolysis, mgm. per 100 cc.

Animal	Blood when drawn		After 2 hours		After 6 hours		After 10 hours		After 14 hours	
	Sugar	Lactic Acid	Sugar	Lactic Acid	Sugar	Lactic Acid	Sugar	Lactic Acid	Sugar	Lactic Acid
Goat 5	49	6	38	16	19	35	13	41	9	41
" 33/3/5	64	19	55	28	39	43	9	52	8	59
" 33/3/6	69	17	58	30	36	51	8	47	8	44
" 33/3/3	52	16	33	36	19	50	8	50	8	47
" 33/3/4	49	14	38	25	19	45	7	46	7	45
" 33/9/1	47	40*	35	56	18	72	8	69	8	64
" 33/3/2	43	13	35	20	20	34	9	37	8	40
Dog 33/3/1	68	11	43	37	22	58	11	65	10	55

* Animal struggled before sample was drawn.

many,[2, 10–12, 15–17] that processes which accelerate glycolysis result in a greater preliminary fall of the inorganic phosphate. From the processes known to accelerate glycolysis, the addition of glucose to the blood was selected for application to goat blood.

Our results on dog blood were entirely similar to those reported in the literature. However, the addition of glucose to goat blood (50 to 100 mg. per 100 cc.) never resulted in a fall of the inorganic phosphate. The usual result was a slight but definite delay in the gradual rise which occurs in the untreated blood. (Fig. 2.) Such a

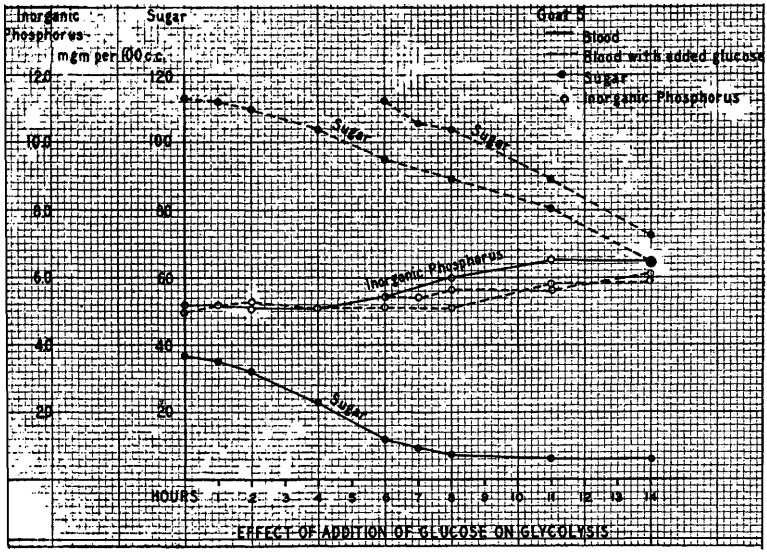

FIG. 2.

Effect of addition of glucose on glycolysis and changes in inorganic phosphate in goat blood. Glucose was added to one portion of the sample at beginning of experiment. Control sample was divided after 6 hours of incubation and glucose added to a portion of it at that point.

delay was produced whether glucose was added immediately after the blood was drawn, or at a time several hours later when the original sugar had almost disappeared. It should be noted, also, that the addition of glucose to goat blood never produced more than a very slight acceleration of the glycolytic rate. In about half the cases there was no acceleration whatsoever.

It has been reported also that measures which check or prevent

11 Kawashima, Y., *J. Biochem.*, Japan, 1923, **3**, 273.

12 Lawaczeck, H., *Biochem. Z.*, 1924, **145**, 351.

14 Martland, M., Hansman, F., and Robison, R., *Biochem. J.*, 1924, **18**, 1152.

16 Rona, P., and Doblin, A., *Biochem. Z.*, 1911, **32**, 489.

17 Rona P., and Iwasaki, K., *Biochem. Z.*, 1927, **184**, 318.

glycolysis result in an immediate release of inorganic phosphate.[1, 7, 12, 14–16] We have been able to confirm these reports in the effect of sodium fluoride on the changes in dog blood.

However, although sodium fluoride, in the proportion of 8 mg. per 100 cc. effectively prevents glycolysis in goat blood, it is, in this case, apparently without effect upon the behavior of the inorganic phosphate. As may be seen by reference to Fig. 3, the curves

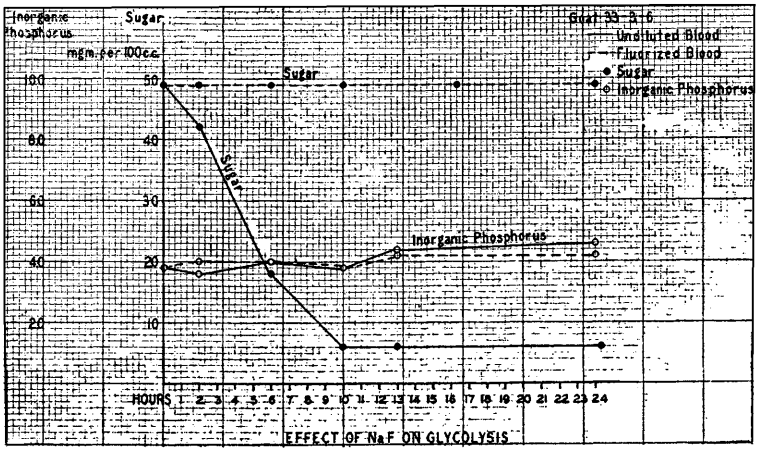

FIG. 3.
Effect of sodium fluoride on glycolysis and changes in inorganic phosphate in goat blood.

illustrating the changes in the level of the inorganic phosphate are entirely similar in the portion of the sample where glycolysis is taking place normally, and in that where it has been suppressed by sodium fluoride. There is, in both cases, only the usual slight gradual rise. Any slight differences in the levels in the 2 portions of the samples are well within the limits of experimental error.

Further data are necessary before these results can be explained satisfactorily. The author is, however, unable at present to pursue the subject further. The results are therefore offered without the additional data necessary for their explanation.

Summary. The changes in the level of the inorganic phosphate which accompany glycolysis in the blood of the dog, the rabbit and the human do not occur in the glycolysing blood of the goat. The addition of glucose to the glycolysing blood of the goat produces only a slight retardation of the gradual rise which normally occurs. The addition of sodium fluoride to the blood of the goat is apparently without effect upon the behavior of the inorganic phosphate.

[1] Barrenschien, H. K., and Braun, K., *Biochem. Z.*, 1931, **231**, 144.