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On the Mechanism of Glucose Absorption from the Intestinal Tract.

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Pierce and collaborators[1] recently published 2 statements: (1) The rate of absorption of glucose falls off during the last hour of a 3 hour period. This, they say, does not agree with Cori's findings. (2) The percentage of glucose absorbed during 1, 2 and 3 hour periods depends upon the amount of glucose remaining unabsorbed in the alimentary tract. The experimental data on which these 2 statements rest, appeared simultaneously elsewhere.[2]

The decrease in the rate of absorption in the third hour is not difficult to explain, because Pierce did not feed enough sugar to let the absorption proceed for 3 hours. Whereas an average of 236 mg. of sugar was absorbed in the first hour and of 229 mg. in the second hour, only 88 mg. of sugar were available for absorption in the third hour. Pierce erroneously assumed that absorption was not completed after 3 hours, because he made no allowance for the blank (sugar plus non-sugar reducing substances) given by empty intestines. In our experiments[3] an average of 235 mg. of glucose remained unabsorbed in the intestine after 3 hours. In this case the blank can be neglected, because it constitutes only a small percentage of the sugar content of the intestine, especially if the determinations are made with the less sensitive Bertrand method. In the experiments of Pierce there remained an average of only 44 mg. of sugar per 100 gm. rat. In 4 individual experiments 24, 10, 24, and 18 mg. of sugar per 100 gm. rat were found remaining in the intestine. This corresponds to an absorption of 95.5 to 97.7% of the sugar fed, which is evidently complete absorption, considering that Pierce used the Folin-Wu method* and made no allowance for the rather high blank which this method gives for intestines of fasting rats.

The fact that Pierce and collaborators found a constant rate of absorption in the first 2 hours, is a confirmation of our results. It was reasonable to expect that the mechanism of absorption would remain the same for all hours and not suddenly change after the

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[1] Pierce, H. B., Osgood, H. S., and Polansky, J. B., PROC. SOC. EXP. BIOL. AND MED., 1929, xxvi, 347.

[2] Pierce, H. B., Osgood, H. S., and Polansky, J. B., *J. Nutrit.*, 1929, i, 247.

[3] Cori, C. F., *J. Biol. Chem.*, 1925, lxvi, 691.

* Personal communication.

second hour. Disregarding his own results, Pierce tries to show by means of a calculation that the amount absorbed is a function of the sugar remaining in the intestine. At the same time, he states that he observed no relationship between the amount of sugar fed and absorbed. Obviously, these 2 statements are contradictory and only one can be true.

The gist of Pierce's calculation is that it is merely a coincidence that Cori observed a constant rate of absorption, because he fed increasing amounts of glucose in the 1, 2 and 3 hour absorption periods, compensating thereby for a decrease in the rate of absorption which otherwise would have occurred in the second and third hour. There is evidence that coincidence plays no rôle in the finding of a constant rate of absorption but is concerned in the rough agreement of Pierce's calculation with the results obtained in one particular set of experiments. Since Pierce repeated these experiments, he also found agreement with his calculation. However, if he had calculated some of our other experiments in which no progressive amount of sugar was fed, he would have noted that the observed and calculated values do not agree at all. This is also shown in the following new experiments in which a constant amount of glucose was fed for each of the absorption periods. (Table I.)

TABLE I.

Four rats each killed 1, 2 and 3 hours after glucose feeding. The average amounts fed per 100 gm. rat were 943 mg. for the 1 hour, 931 mg. for the 2 hour and 951 mg. for the 3 hour absorption period. The average body weight of the 3 groups of rats was 140.5, 142.6 and 138.2 gm. respectively.

Glucose absorbed per 100 gm. rat.

0 to 1 hour		0 to 2 hours		0 to 3 hours	
mg.	%	mg.	%	mg.	%
200	17.7	470	45.2	666	66.7
232	24.7	438	51.1	693	75.3
166	19.0	458	51.2	690	76.6
214	25.5	510	54.6	594	65.0
203	21.7	469	50.5	660	70.9
Expected according to Pierce*		363	38.6	489	51.9

*Calculation: Since 21.7% of 943 is absorbed in the first hour, 740 mg. of sugar are left in the intestine after one hour. 21.7% of 740 is supposed to be absorbed in the second hour, leaving 578 mg. for the third hour and so on.

The results in Table I are those usually obtained when young and healthy male rats of uniform age and weight are used. Pierce departed in this particular from the method as originally described, since he used less uniform and much heavier rats.

The experiments in Table I show that the rate of absorption is not a function of the amount of sugar present in the intestine. If such were the case, the observed and calculated values would agree. Also, there is no falling off in the rate of absorption in the third hour even though only 29% of the sugar fed remains in the intestine unabsorbed. Previous experiments showed that absorption can proceed still further or can even go to completion without leading to a noticeable decrease in the rate of absorption. This is strikingly illustrated in new experiments which were carried out to emphasize this point again. (Table II.)

TABLE II.
Killed 3 hours after glucose feeding.

Body weight	Per 100 gm. of body weight			% absorbed
	Glucose fed	Glucose remaining in intestine	Glucose absorbed	
gm.	mg.	mg.	mg.	
138.2	706	14.3	692	98.0
110.5	719	28.2	691	96.1
125.0	730	58.0	672	92.1
121.7	712	29.6	682	95.8
	717	33.0	684	95.5
Average of Table I			660	

The highest absorption in the 3 hour period in Table I was 693 mg. per 100 mg. rat. Slightly more than this amount (717 mg.) was fed to 4 rats and the sugar remaining in the intestine after 3 hours was determined.* In this way just enough sugar is introduced to permit the absorption to proceed for 3 hours and consequently the sugar in the intestine falls to a low value toward the end of the 3 hour absorption period. Since the absorption proceeds at an average rate of 660/3 = 220 mg. per hour (Table I), 100 mg. or 14% of the glucose fed would be left in the intestine after 150 minutes. If this small amount of residual sugar were a limiting factor, the rate of absorption would diminish in the last half hour, and consequently more sugar would remain in the intestine than was found experimentally (Table II).

Perhaps no better example can be offered for the fact that the rate of absorption of glucose is uninfluenced, within widest limits, by the amount of sugar present in the intestine than the experiments

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* The intestinal washings were precipitated with colloidal iron and made up to 200 cc. An aliquot portion of the filtrate was shaken out with Lloyd's reagent and the reducing value was determined by means of the Hagedorn and Jensen method. The Lloyd filtrate was treated with copper sulfate and lime in order to remove sugar and the reducing value again determined. The difference represents sugar in the sample. In the experiments in Table I, where more sugar was left in the intestine, Bertrand's method was used.[3]

in Table II. It may be mentioned that other substances are not absorbed in the same way as sugars. For instance, the rate of absorption of sodium lactate depends on the amount fed.[4] The mechanism of absorption of other substances will soon be reported.

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Influence of Food Fat on the Constitution of the Phospholipids.

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In the course of an investigation concerning the mechanism of fat absorption, it was thought that possibly the phospholipids of the intestinal mucosa are intermediary products in the process of fat resynthesis from the absorbed fatty acids and glycerol. If this be true, during the absorption of fat the constituent fatty acids of the phospholipids in the mucosa must consist, in part at least, of the fatty acids of the ingested fat. In order to test this idea it was decided to see if the absorption of such fats as cod liver oil and cocoanut oil (which are characterized by high and low degrees of unsaturation, respectively) produces a change in the iodine absorption value (I.N.) of the phospholipid fatty acids in the absorbing mucosa. Later the investigation was extended to include a study of the effect of fat absorption and of different continued diets on the constitution of the phospholipids of the intestinal and skeletal muscles and of the liver.

The experimental plan was as follows: To one of a pair of cats which had been kept on the same diet for 2 weeks or longer either cod liver oil or cocoanut oil was administered by stomach tube; some time later (usually 5-7 hours) the animal was killed. The other cat was killed in a post-absorptive state to serve as a control. The mucosa and the muscle of the small intestine were separated; the muscles of one hind leg were used to typify skeletal muscle. The lipids were extracted with hot alcohol and the phospholipids were isolated and purified by acetone precipitation from ether solution, according to the method of Bloor.[1] After saponification of the phospholipids, the weight and I.N. of the constituent fatty acids were determined.

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[4] Cori, C. F., and Cori, G. T., *J. Biol. Chem.*, 1929, lxxxi, 389.

[1] Bloor, W. R., *J. Biol. Chem.*, 1926, lxviii, 33.