COUPLING OF MEMBRANE HYDROLYSIS WITH CARBOHYDRATE TRANSPORT IN THE RAT SMALL INTESTINE

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The mucosal and serosal transport of glucose was studied in experiments in vitro in 6 segments of the rat small intestine from equivalent solutions of starch, maltose, and glucose. In intact animals, in the case of transport along the electrochemical gradient, glucose formed by hydrolysis of maltose was absorbed faster than free glucose, and these differences increased as incubation continued. In the presence of phloridzin, transport of the oligomers was depressed to a greater degree than glucose transport. Ligation of the pancreatic and common bile ducts reduced the degree of coupling of membrane hydrolysis with transport in the early stages after the operation but increased it toward the end of the first month of observation.

Recent investigations have shown that hydrolysis of nutrient substances takes place on the outer surface of the cell membranes of the intestinal epithelium, and the initial stages of absorption are also carried out there [2-5]. Under certain experimental conditions [3, 8-10] the rate of absorption of ready-made monomers is slower than the rate of absorption of monomers formed by hydrolysis of polymers and oligomers. One hypothesis put forward to explain this phenomenon is that of the digestive-transport conveyor [3-5]. In the present investigation the absorption of glucose from equivalent solutions of starch, maltose, and glucose was studied. Attention was paid to the relative concentrations on either side of the intestinal mucosa and the role of active transport mechanisms.

EXPERIMENTAL METHOD

Experiments were carried out on 68 adult albino rats previously starved for 15 h.

Muscoal and serosal transport of glucose along the electrochemical gradient and in the presence of phloridzin ($5 \cdot 10^{-5}$ M) was studied in intact animals (experiments of series I). A modified "everted pouch" method [4, 12] was used. In the experiments of series II the accumulation of glucose was investigated in an accumulating preparation of the mucosa [6] from control animals (undergoing a mock operation) and from rats on the 4th, 7th, 14th, and 28 days after ligation of the pancreatic and common bile ducts. In both series these indices were studied in 6 segments of the small intestine (without the duodenum). The preparations of intestine were incubated in a 0.2 % saline solution (pH 7.4) of the corresponding substrate (glucose, maltose, starch) at 37°C with continuous aeration. The content of reducing sugars was determined by Nelson's method in Ugolev's modification [7].

EXPERIMENTAL RESULTS

Preliminary experiments showed that during three successive incubations (each for 30 min) the transport of free glucose (G-glucose) by the same segment of the small intestine did not change significantly. It was accordingly postulated that the dynamics of absorption of glucose formed by hydrolysis of maltose (M-glucose) would be determined primarily by interaction between the hydrolytic and transport processes.

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TABLE 1. Transport of Glucose (in mg %) by Different Segments of the Small Intestine of Intact Rats during Three Consecutive Incubations in 0.2% Solutions of Glucose and Maltose (M±m)

Incubation medium	Incubation time (in min)	Segments of small intestine					
		1	2	3	4	5	6
Glucose	0—30	166,8±14,7	182,8±23,6	185,8±21,1	152,8±28,1	103,4±14,5	30,7±3,4
	30—60	191,8±12,8	216,6±31,1	221,2±29,5	181,6±41,0	115,2±24,1	26,5±0,5
	60—90	178,8±17,7	192,0±30,1	177,6±29,3	148,2±43,4	100,0±26,2	26,0±1,7
Maltose	0—30	193,3±22,4	199,5±31,0	202,7±28,0	210,2±22,9	175,0±26,1	55,7±11,2
	30—60	253,0±13,3	266,5±26,1	279,2±41,4	261,2±30,3	198,5±30,3	51,0±19,1
	60—90	268,7±9,7	273,2±15,7	287,7±52,8	227,7±61,1	174,7±33,5	47,3±12,9
Glucose + phloridzin	0—30	23,6±5,0	30,6±6,0	40,6±5,5	50,0±9,0	28,8±9,9	7,7±4,5
	30—60	35,6±7,9	50,8±6,5	62,6±8,0	69,0±12,7	36,4±5,6	20,5±8,1
	60—90	41,0±6,7	57,0±6,3	71,4±7,6	66,4±8,2	43,6 ±10,4	20,0±3,3
Maltose + phloridzin	0—30	20,6±2,3	19,7±1,5	41,2±6,8	34,6±7,1	22,0±2,7	2,4±0,8
	30—60	31,4±3,2	33,0±4,2	53,5±1,8	55,0±7,1	20,0±4,1	0
	60—90	34,8±6,9	31,5±6,0	51,2±2,3	41,5±5,4	22,5±5,4	0

TABLE 2. Changes in Coefficient of Coupling of Membrane Hydrolysis with Transport of Starch in Segments of the Rat Small Intestine after Ligation of Pancreatic and Common Bile Ducts (M±m)

Segment of small intestine	Control	Days after ligation of ducts			
		4	7	14	28
1	1,07±0,26	0,42±0,02	0,72±0,07	0,89±0,06	0,95±0,09
P		<0,05	>0,2	>0,2	>0,5
3	0,72±0,03	0,41±0,02	0,53±0,03	0,71±0,06	0,81±0,02
P		<0,001	<0,01	>0,5	<0,02
6	0,81±0,05	0,38±0,04	0,84±0,06	0,81±0,04	1,14±0,15
P		<0,001	>0,5	>0,5	<0,05

Note. P relative to control.

With the chosen incubation program and transport along the electrochemical gradients M-glucose was absorbed more rapidly than G-glucose. However, as Table 1 shows, the quantitative relationships between these parameters differed from one segment of the small intestine to another and varied in the course of the experiment. In the 1st, 2nd, and 3rd segments the absorption of M-glucose rose considerably as incubation continued and was significantly ($P < 0.05$) higher than the transport of G-glucose.

In the presence of phloridzin the absorption of glucose and maltose fell sharply in all parts of the small intestine. A change in the dynamics of absorption of M-glucose with time was observed, and the efficiency of its transport through the intestinal wall was lower than that of G-glucose. Considering that phloridzin, in the concentration used, blocks the system of specific carriers on the outer surface of the intestinal cell membrane [11], it must be concluded that M-glucose is carried by mechanisms of active transport which are less resistant to blocking.

In the experiments of series II changes in coupling between membrane hydrolysis and carbohydrate transport were studied when the conditions of digestion of nutrient substances were disturbed. For this purpose, the accumulation of G-glucose and of glucose formed by hydrolysis of starch (S-glucose) was determined in each experimental animal, so that the starch–glucose ratio could be calculated [1]. The results showed that on the 4th day after ligation of the pancreatic and common bile ducts this ratio fell (Table 2) in the proximal, middle, and distal portions of the small intestine. However, by the end of the first week after the operation signs of compensation were observed, for the ratio had reached the control level in segments 1 and 6. At later times of observation the absorption of S-glucose increased more than that of G-glucose, and on the 28th day after the operation the starch–glucose ratio in segments 3 and 6 was significantly higher than in the control.

These results thus confirm the view that coupling between hydrolysis and transport processes in the zone of contact digestion creates real advantages for the transport of oligomers over that of ready-made monomers. The increase in the efficiency of transport of M-glucose as incubation continues indicates functional reconstruction in the "enzyme–carrier" system and can be interpreted in the light of the hypothesis of integrative induction in the digestive-transport conveyor [4, 5]. In experimentally induced pathology of the digestive process, an increase in the degree of coupling of membrane hydrolysis with transport was found, and this may play a definite role in the development of adaptive and compensatory reactions in the small intestine.

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