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The permeability of liver and muscles for hexoses and pentoses.

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Preceding work has shown that the epithelial cells of the intestine are selectively permeable for different sugars, while the epithelial cells of the peritoneal cavity are equally permeable for all sugars. It seemed of interest to study how other cells of the body, especially those of liver and muscle, behave in this respect. For this purpose sugar was injected intravenously and the animals killed in very short time intervals after the injection. By determining the ratio between the sugar concentration in the blood and in the different tissues conclusions as to the permeability of the tissues could be drawn.

Experimental

Full grown white mice, previously fasted for 24 hours, were used. The injections were made into the tail vein and were timed with a stop watch. Four tenths cc of a 15 per cent sugar solution were injected within 14 to 18 seconds. The animals were then killed exactly 1, 2 and 3 minutes after the start of the injection. Liver and muscles were quickly removed and frozen with compressed CO_2. The organs were weighed in the frozen state and ground up with ice cold 2 per cent HCl. The grinding of the muscles was facilitated by the addition of a small quantity of sand. The proteins were precipitated with 5 per cent H_gCl_2 and the samples were left standing for 1 to 2 hours. After the removal of the mercury in the usual way and neutralisation, the sugar was determined in an aliquot part of the filtrate.

TABLE I.

The permeability of liver and muscles of mice for hexoses and one pentose. Four tenths cc. of a 15 per cent sugar solution, or 60 mg., were injected intravenously and the animals killed 1, 2 and 3 minutes after the start of the injection. Each figure is an average of 2 to 3 experiments.

Type of Sugar	1 minute			2 minutes			3 minutes		
	Blood sugar.	Liver sugar.	Muscle sugar.	Blood sugar.	Liver sugar.	Muscle sugar.	Blood sugar.	Liver sugar.	Muscle sugar.
	Per cent.	Per cent.	Per cent.	Per cent.	Per cent.	Per cent.	Per cent.	Per cent.	Per cent.
d—Galactose	0.980	0.761	0.223	0.861	0.683	0.235	0.759	0.641	0.272
d—Glucose	1.01	0.718	0.243	0.847	0.670	0.240	0.722	0.657	0.279
d—Fructose	1.07	0.756	0.213	0.865	0.681	0.212	0.741	0.631	0.303
d—Mannose	1.02	0.746	0.268	0.850	0.719	0.221	0.737	0.672	0.271
l—Arabinose	1.09	0.715	0.214	0.841	0.669	0.237	0.750	0.622	0.262

TABLE II.

The ratio between sugar concentration in the blood and in liver and muscle has been calculated from the figures in Table I. The blood sugar concentration has been taken as 100.

Type of sugar.	1 minute		2 minutes		3 minutes	
	Liver sugar.	Muscle sugar.	Liver sugar.	Muscle sugar.	Liver sugar.	Muscle sugar.
d—Galactose	77.6	22.8	79.3	27.3	84.5	35.8
d—Glucose	71.1	24.1	79.1	28.3	91.2	38.6
d—Fructose	71.5	19.9	78.7	24.5	85.1	40.8
d—Mannose	73.2	26.2	84.5	26.0	91.1	36.8
l—Arabinose	65.5	19.6	79.5	28.2	83.0	34.9

The data of Tables I and II indicate that the cells of liver and muscle are not selectively permeable for the different sugars investigated. The variations in the different values are within the limit of error of the method.

It is interesting to note how extremely rapidly the sugar leaves the blood stream. A mouse of 20 grams has a blood volume of about 1.5 cc. Since 60 mg. of sugar in 0.4 cc fluid were injected, the blood sugar concentration should rise to about 3 per cent. Yet, within 1 minute from the start of the injection the blood sugar concentration is only 1 per cent. In the following 2 minutes the blood sugar diminishes very slightly, when compared with the initial, abrupt fall. The sugar concentration in the liver also decreases in the second and third minute after the injection. This indicates that an equilibrium between the sugar concentration of the blood and of the liver is reached in 1 minute after the injection. The sugar concentration in the muscles increases slightly in the second and markedly in the third minute after the injection. An equilibrium between the sugar concentration of the blood and of the muscle is not yet reached. It may be concluded that the muscles are decidedly less permeable for sugars than the liver. This may be due to the smaller blood supply of the muscles as compared with that of the liver.

Summary

1. When 60 mg. of sugar are injected intravenously into mice of 20 gram body weight an equilibrium between the sugar concentration of the blood and of the liver is reached in 1 minute after the start of the injection.

2. Different hexoses and the one pentose examined reach this

equilibrium at the same rate and hence penetrate with equal rapidity into the liver cells.

3. The muscles are less permeable for sugar than the liver. The ratio blood sugar: liver sugar : muscle sugar, 3 minutes after the injection, is of the order, 100 : 87 : 37.

4. The different sugars investigated penetrate into the muscle cells at the same rate.

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The tolerance of rats for intravenously injected glucose.

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It has been found that rats absorb from the intestine 1.78 grams glucose per kilogram body weight per hour without showing glycosuria. Since, also, equal amounts of sugar were found to pass from the intestine into the blood stream in equal periods of time, the absorption is comparable with a continuous intravenous infusion at a constant rate. Woodyatt, Sansum and Wilder[1] determined the glucose tolerance of normal rabbits, dogs and men by the continuous intravenous infusion method. They found that if glucose was infused at a rate of 0.85 gram per kilogram an hour, no glycosuria was produced, even if the infusion was extended over many hours. This is obviously a much lower tolerance than that observed on rats during intestinal absorption. There seemed to be two explanations possible. Either the rat has a higher glucose tolerance than rabbit, dog or man, or, the glucose tolerance, when tested by the intestinal route, is higher than when tested by the intravenous route. In order to see which of the two explanations is correct the sugar tolerance of rats was tested by the intravenous infusion method.

Experimental.

Non-fasting male and female rats were used. The experi-

[1] Woodyatt, R. T., Sansum, W. D., and Wilder, R. M., *J. Am. Med. Assn.*, 1915, lxv, 2067.