heat of the x-ray window alone and to what extent absorbed x-ray energy in the thermocouple itself contributes to the temperature change. It could be very well possible that the actual window temperature is lower than the thermocouple indicates.

Fig. 5 shows changes of body temperature during x-ray exposure of animals cooled by ice water. In all instances temperature was reduced below normal, and life was prolonged regardless of treatment area. At the very least a doubling of dose was required to kill the animal within 25 minutes.

Additional information has been sought by investigating changes in breathing pattern, electrocardiogram tracings, as well as blood changes and histological picture, since the above findings present a variety of possible reasons for super-acute radiation death of the animals. Results obtained in these studies are being analyzed.

Summary. The effects of extremely high x-ray dose rates and dosages on mice irradiated at normal and subnormal body temperatures were studied. Considerable lengthening of survival time is obtained when body temperature is lowered during irradiation. A slight elevation of body temperature during irradiation was noticed.

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Carbohydrates and Gastrointestinal Absorption of Radiostrontium and Radiocalcium in the Rat.* (24922)

R. H. WASSERMAN AND C. L. COMAR
Lab. of Radiation Biology, N. Y. State Veterinary College, Cornell University, Ithaca, N. Y.

Ability of lactose to increase gastrointestinal absorption and retention of calcium has been known for many years and has been adequately confirmed under various conditions and in different species. The effects of lactose on calcium metabolism and other physiological functions have been reviewed recently by Duncan(1) and Atkinson *et al.*(2). Although the action of lactose has been widely studied, little attention, with one exception, has been given to the influence of other sugars and sugar derivatives on calcium. Fournier and his colleagues(3-5) determined the net retention of calcium in rats as influenced by ingestion of sugars by use of conventional calcium balance technic. Certain sugars, in addition to lactose, were capable of enhancing calcium retention in the growing and lactating rat; *e.g.*, xylose, mannose, raffinose, mannitol and sorbitol. It was not feasible with calcium balance method to determine extent

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to which carbohydrates increased gastrointestinal absorption or acted by direct effect on skeletal growth. The work presented here, based on tracer procedures, distinguishes between skeletal and absorptive effects. The technic was used to estimate effect of various sugars and sugar derivatives on gastrointestinal absorption of radiocalcium and radiostrontium in a way similar to that previously described for study of the influence of various amino acids on intestinal absorption(6).

Materials and methods. Male rats of Wistar strain weighing about 90-110 g were fasted 24 hours with only drinking water available. At this time, the rats were lightly anaesthetized with ether and given, by gavage, 1 ml of test solution containing 20 μc Ca^{45}, 2 μc Sr^{85}, 0.42 millimole of test substance and 0.04 millimole of calcium chloride. The animals were killed at 24 hours after dosing and the femurs removed for radioassay. Calcium 45 was determined by oxalate-precipitate method described by Comar(7) and Sr^{85} was measured by counting excised whole femur in a well-type scintillation detector. It has previously been shown that the appearance of Ca^{45} and Sr^{85} in bone 24 hours after oral administration is a measure of gastrointestinal absorption(6) and, more specifically, that lactose administered under similar conditions does not directly influence movement of alkaline earths from blood to bone(8). In the latter study, the ratio of femur Sr^{85} to absorbed Sr^{85} as directly measured was not affected by presence of lactose. Radioassay data are expressed in terms of "% of administered dose" or as "% of ingested dose."

To study further this lack of lactose effect on skeletal metabolism, a balance-type technic was employed in which young growing male rats on Rockland stock diet were placed on diets that contained either 30% sucrose or 30% lactose. When rats were placed on experimental diets, the drinking water was replaced with distilled water containing 0.02 μc Sr^{85}/liter; the rats were continued on this regime for 7 days. By use of graduated drinking tubes, the volume and therefore the amount of activity ingested was determined. Radiostrontium or radiocalcium ingested in this manner has been shown to equilibrate with, and be metabolized similarly to, dietary calcium in the young growing rat(9). The feces and urine were collected separately over the 7-day period and at this time the rats were killed and the contents of the digestive tract was removed and combined with the pooled feces. The pooled feces plus digestive tract contents, pooled urine samples and the left femur from each rat were radioassayed for Sr^{85}.

Carbohydrates were obtained from Nutritional Biochemicals Corp., and used without further purification. All sugars employed were the natural forms.

Results. The data on comparative effect of a number of sugars and sugar derivatives on radiostrontium absorption and, in certain instances, on radiocalcium absorption are summarized in Table I. This compilation represents 3 separate experiments in which femur Sr^{85} values for control groups were standardized to a value of 1.3% for comparative purposes. However, results from each experiment were treated by analysis of variance method to determine any statistical significance of effects of test substances. First, there was parallel behavior between Ca^{45} and Sr^{85} in regard to effects on absorption, *e.g.*, xylose and lactose increased absorption of both alkaline earths whereas glucose and galactose had no effect on either ion. This parallelism holds in this laboratory for numerous substances, including some 20 amino acids and Vit. D(6,8,10).

Although radiostrontium responds qualitatively in the same way as does radiocalcium, there are certainly quantitative differences in over-all metabolism of these alkaline earths, a subject that has been studied intensively (11). Differences in the present study are shown by Sr^{85}/Ca^{45} ratios listed in Table I; here the Sr^{85}/Ca^{45} ratio of the ingested solution is taken as unity. The Sr^{85}/Ca^{45} ratio of 0.61 for the control group indicates that proportionally more Ca^{45} than Sr^{85} was transported from gut to bone. There was a definite increase in the Sr^{85}/Ca^{45} ratios of xylose and lactose-treated groups; this elevation of the Sr^{85}/Ca^{45} ratio by substances that en-

TABLE I. Influence of Carbohydrates on Gastrointestinal Absorption of Sr^{85} and Ca^{45} in the Rat.

Test substance	Femur conc. of radionuclide* (% dose/femur) Sr^{85}	Ca^{45}	Sr^{85}/Ca^{45}	Change in femur Sr^{85} content (%)	Effectiveness in enhancing Sr^{85} absorption (present study)	Effectiveness in enhancing Ca. retention (after Fournier *et al.*) †
Control	$1.3 \pm .1$	$1.9 \pm .1$	.61			
D-Glucose	$1.1 \pm .1$	$2.1 \pm .2$	.50	− 15	ineffective	ineffective
Sucrose	$1.4 \pm .1$			+ 8	"	"
D-Galactose	$1.5 \pm .1$	$2.5 \pm .2$	.61	+ 15	"	slightly effective
D-Fructose	$1.6 \pm .2$			+ 23	"	
Cellobiose	$2.1 \pm .2$			+ 62	effective	
L-Sorbose	$2.5 \pm .1$			+ 92	"	effective
D-Ribose	$2.5 \pm .2$			"	"	
D-Xylose	$2.6 \pm .4$	$3.6 \pm .3$	.71	+100	"	effective
Lactose	$2.6 \pm .4$	$3.2 \pm .2$	.76	"	"	"
Raffinose	$2.6 \pm .2$			"	"	"
Melibiose	$2.6 \pm .3$			"	"	"
D-Glucosamine	$2.7 \pm .2$			+108	"	
D-Mannitol	$2.8 \pm .2$			+115	"	effective
D-Sorbitol	$2.8 \pm .3$			"	"	"

* Values represent mean ± stand. error of mean; 6 rats/group; mean body wt about 90-110 g.

† See text for references.

hance alkaline earth absorption had been noted previously(6). The reason for this change in ratio is unknown but may be due to mass effects or the effect of these substances on processes of discrimination.

The relative effectiveness of test substances on Sr^{85} absorption may be readily noted in column 5 of Table I. The Sr^{85} contents in femurs of glucose, galactose, sucrose and fructose-treated groups were not significantly different from those of control group. All other sugars or their derivatives greatly enhanced Sr^{85} absorption, with cellobiose being least effective. Also in Table I, the data of Fournier *et al.* (*loc cit*) as obtained from the balance technic are summarized for comparison. There is excellent agreement between the 2 studies.

In Table II, results of the balance study with Sr^{85} are presented. The lactose-supplemented group absorbed and retained more of the ingested Sr^{85} than did the sucrose-supplemented group when measured directly or by bone content; these differences were significant at $p<0.01$. An important conclusion from this study is that the enhanced retention of Sr^{85} was accounted for by increased gastrointestinal absorption of Sr^{85}. This is shown by the similarity of "absorbed-retained" ratios for the 2 groups. Thus, there was no evidence that lactose had a direct effect on skeletal metabolism in these studies.

Discussion. From our study, it seems apparent that there was no general pattern of specificity in enhancement of Ca^{45} and Sr^{85} absorption by carbohydrates. Also there did not appear to be any correlation between effectiveness in promoting alkaline earth ab-

TABLE II. Comparison of Sucrose- and Lactose-Supplemented Diets on the Absorption and Retention of Radiostrontium.*

Diet	Fecal excretion of Sr^{85} (% ingested dose) †	Urinary excretion of Sr^{85} (% ingested dose) †	% absorption of Sr^{85} (by difference)	% retention of Sr^{85} (by difference)	Femur content of Sr^{85} (% ingested dose) †
Sucrose	78 ± 3	$2.4 \pm .3$	22	20	$.82 \pm .09$
Lactose	68 ± 2	$4.4 \pm .8$	32	28	$1.18 \pm .04$

* Basal diet contained casein 20%, starch 33%, vegetable oil 10%, brewer's yeast 2%, salt mixture U.S.P. #2 4%, vit. supplement (Nutritional Biochemical) 1%; sucrose and lactose added at 30%; 5 rats/group with mean initial body wt of 193 g.

† Values represent % of total ingested Sr^{85} that was excreted in feces and urine over the 7 day experimental period; data given as mean ± stand. error of mean.

sorption and any usual physical or chemical properties of the carbohydrate, which included pentoses, hexoses, disaccharides, trisaccharides, hexitols and hexosamines. This was in contrast to the specificity of the influence of individual amino acids on Ca^{45} and Sr^{85} absorption where L-lysine and L-arginine were more effective than any of 20 amino acids tested(6).

An interesting relationship may exist, however, between the physiological behavior of carbohydrates and their ability to enhance Sr^{85} absorption and calcium retention. Glucose and galactose are absorbed rapidly from the digestive tract and essentially by active metabolic processes; rate of absorption of glucose and galactose is decreased by presence of monoiodoacetic acid, phlorizin, an abnormal pH, and takes place at a constant rate, independent of concentration(12). Fructose absorption also occurs rapidly but takes place by 2 processes: simple diffusion and an active process that depends on transformation of intestinal fructose to glucose(12). The pentoses, sorbose and glucosamine are absorbed by passive diffusion as reported by Verzár(12) and Wilson and Vincent(13). Among disaccharides, lactose is absorbed more slowly than sucrose(14), the difference probably being due to the less rapid hydrolysis of lactose by intestinal enzymes. Cellobiose is absorbed much less rapidly by the rat than is glucose but can be utilized for glycogen synthesis(15). Information on comparative rates of absorption of sorbitol, mannitol, raffinose and melibiose or their comparative rates of enzymatic hydrolysis was not found. Thus, from information available, it appears that effectiveness in enhancing Sr^{85} absorption and calcium metabolism may be positively correlated with 2 physiological characteristics: (a) prolonged residence time of the effective carbohydrate in the gastrointestinal tract or (b) absorption by a passive mechanism. Although the exact meaning of this apparent relationship is not known, it is indicated from these studies that the site of action of effective carbohydrates is the gastrointestinal tract. This is in contrast to the theory of Fournier *et al.* (*loc cit*) that lactose, xylose, and other stimulatory sugars operate by directly influencing skeletal ossification.

Summary. 1. The influence of 14 carbohydrates on gastrointestinal absorption of radiostrontium and radiocalcium was studied in the rat. 2. Cellobiose, sorbose, ribose, xylose, lactose, raffinose, melibiose, glucosamine, mannitol and sorbitol significantly enhanced alkaline earth absorption whereas glucose, galactose, fructose and sucrose had little or no effect. 3. In a balance-type study with Sr^{85}, enhanced retention due to dietary lactose as compared with dietary sucrose could be accounted for by increased intestinal absorption rather than by direct effect on skeletal ossification. 4. Effectiveness in ability to enhance calcium and strontium absorption appeared to be positively correlated with a prolonged residence time of the carbohydrate in the gut or absorption of carbohydrate by a passive mechanism.

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