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Intake of a Liquid Diet After 2-Deoxy-D-Glucose Injections in Rats[1]

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WATSON, P. J., D. H. RHODES, K. RHEA, J. McKINNEY, C. HAWKINS AND R. R. BARTLES. *Intake of a liquid diet after 2-deoxy-D-glucose injections in rats.* PHARMACOL BIOCHEM BEHAV **25**(6) 1153–1158, 1986.—The effects of a liquid diet after 2-deoxy-D-glucose (2DG) were examined following water deprivation, after food deprivation, and at longer post-injection intervals when animals reportedly are hypophagic as a function of drug treatment. Water deprived rats were unable to increase their post-drug feeding when ingesting the liquid diet; and in food deprived subjects, intake patterns of liquid diet and of lab chow pellets were essentially identical after 2DG. The tendency of a 750 mg/kg dosage to produce a longer-term hypophagic reaction was more evident in animals given pellets instead of the liquid diet. While previous studies have found the liquid diet to promote 2DG-induced feeding in lesioned subjects, the present data demonstrate that such facilitation effects do not invariably occur during post-drug conditions in which animals are inhibited in their intake.

2-Deoxy-D-glucose Glucoprivation Liquid diet Food deprivation Hypophagia Water deprivation

RESEARCH into the physiology of feeding behavior frequently employs 2-deoxy-D-glucose (2DG), a drug used to inhibit cellular glucose metablosim [12]. The resulting cellular glucoprivation is followed in the short term by increases in food intake, and the correlation between these two events is one support for the argument that glucose availability is an important systemic variable controlling food intake [8]. Responsivity to this glucoprivic stimulus is dependent upon a number of factors including time of injection [7], species of subjects [11], diet palatability [5], hydrational status [19], and functional integrity of such brain structures as the lateral hypothalamus [21], zona incerta [18], and globus pallidus [9].

Brain lesions that disrupt 2DG-induced feeding are frequently interpreted as evidence that the destroyed neural tissues contained neurons monitoring glucose levels and activating food ingestion during conditions of need. However, such interpretations have been rendered problematic by a number of recent observations. Rats with lateral hypothalamic (LH) lesions can increase their food intake after 2DG if care is taken to administer lower dosages that apparently serve as less stressful regulatory challenges [13]. In addition, LH lesioned animals display a more-or-less dose-response relationship between 2DG and their caloric intake when a liquid diet is substituted for the more typical laboratory chow [6]. Presentation of the liquid diet also disinhibits post-2DG feeding in rats with zona incerta lesions [14]. These demonstrations reveal that the ability to process and to respond to the glucoprivic stimulus survives in brain damaged subjects; however, the reasons why such procedural manipulations work against the deficit remain unclear.

Analysis of the liquid diet effects has focussed on the possibility that the palatability dimension is critical. Adulterating powdered laboratory chow with quinine disrupts 2DG-elicited feeding [5], indicating along with other evidence that glucoprivation may be associated with a hyperreactivity to aversive tastes [17]. Destruction of the lateral hypothalamus [4] and the zone incerta [3] both produce finickiness; and taken together, these 2DG and lesion effects suggest that the liquid diet may enable glucoprivic feeding in brain-damaged animals by avoiding the aversive taste properties associated with the presumably less palatable laboratory chow.

The general purpose of the present investigation was to continue analysis of the liquid diet by examining its effects during other experimental conditions in which animals reportedly display a diminished responsivity to 2DG.

EXPERIMENT 1

Some, though not all research [6] suggests that rats in a state of hydrational need are less able to eat in response to the 2DG glucoprivic challenge. This is evident in animals placed on a long-term 23.5-hr water deprivation regimen [19] and also in subjects presented with quinine adulterated water supplies [19,20]. This first experiment sought to determine what effects if any the liquid diet would have on 2DG responsivity in thirsty rats. In addition, a water deprivation regimen different from that used by previous researchers [19] was utilized in order to expand the analysis of this variable.

METHOD

Subjects

Thirty-two experimentally naive, fully adult male rats served as subjects. They weighed 540.7±7.4 g (mean±

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TABLE 1

CUMULATIVE PELLET AND LIQUID DIET INTAKE (MEAN ± S.E.M.) OF 0-, 24-, OR 48-HR WATER DEPRIVED RATS WITH WATER (W) OR WITHOUT WATER (NW) MADE AVAILABLE AFTER 2 DG AND CONTROL (CON) INJECTIONS

			Cumulative Pellet Intake				Cumulative Liquid Diet Intake			
			Post-Injection Hour				Post-Injection Hour			
Group	Injection		1	2	3	4	1	2	3	4
W-0	2DG	Mean	4.14	7.43	11.84	15.71	3.85	7.98	15.26	17.05
		S.E.M.	1.24	1.36	1.77	2.29	0.87	1.59	2.31	2.59
	CON	Mean	0.90	2.75	3.02	5.00	4.81	7.29	7.98	8.39
		S.E.M.	0.35	0.83	0.83	1.14	1.76	2.97	3.24	3.37
NW-0	2DG	Mean	2.48	5.90	9.50	10.98	7.43	14.03	17.74	21.18
		S.E.M.	0.63	1.00	1.36	1.28	1.76	1.84	1.95	2.16
	CON	Mean	1.49	2.93	3.69	5.04	12.51	16.78	17.88	19.53
		S.E.M.	0.74	0.87	1.04	1.22	1.66	1.71	1.54	1.66
NW-24	2DG	Mean	2.62	5.00	6.84	7.74	7.70	17.05	21.18	23.93
		S.E.M.	0.67	0.86	0.80	0.82	1.50	2.99	2.33	1.92
	CON	Mean	1.85	2.70	3.42	4.10	15.13	19.11	22.14	25.44
		S.E.M.	0.60	0.76	0.78	1.01	0.97	1.80	2.29	2.87
NW-48	2DG	Mean	1.71	4.23	5.18	6.17	7.43	12.79	17.05	21.86
		S.E.M.	0.42	0.42	0.69	1.04	1.52	1.36	1.86	1.73
	CON	Mean	1.49	1.76	1.98	2.84	16.23	20.35	23.38	26.68
		S.E.M.	0.58	0.60	0.63	0.98	2.19	1.54	2.03	2.39

S.E.M.) and were obtained from the departmental colony bred from stock originally purchased from Blue Spruce Farms (Altamont, NY).

Procedure

All subjects were housed individually in 7×7×9.5 in. stainless steel cages and were maintained in a room in which ambient temperature was thermostatically controlled at 72°F. Lights were turned on at 8:00 hr and turned off at 20:00 hr.

Animals were assigned to one of four groups (N=8 in each) in a quasi-random manner that guaranteed approximately equal group body weights. Water-No Deprivation (W-O) rats received ad lib water throughout all procedures. Each of the other three groups had no water (NW) during the experimental trials which were preceded by either 0-hr (NW-0), 24-hr (NW-24), or 48-hr (NW-48) fluid deprivation. The project was conducted in two phases with Purina Lab Chow pellet consumption examined first, followed by analysis of the liquid diet.

Preliminary adaptation of subjects to procedures was accomplished through IP injections of physiological saline on the three days prior to data collection. Experimental trials began at approximately 13:00 hours on the next day and lasted for four hours. 2DG (Sigma Co., 10% w/v in distilled water) at a 750 mg/kg dosage level was administered to half of each group during the first session, and physiological saline was given to the other half. At appropriate intervals before the sessions, water was removed from the home cages of NW-24 and NW-48 rats. In addition to the pellet intake of all four groups, the 4-hr drinking totals of the W-0 animals were also recorded. One week later these procedures were repeated, but with the injection condition reversed.

Immediately after this first phase, all animals had their supply of Purina Lab Chow (3.6 kcal/g) supplemented with ad lib access to the liquid diet (1.1 kcal/ml) used in previous investigations: one package of vanilla flavored Carnation Instant Breakfast (35.2 g), 238 ml homogenized whole milk, 1.0 ml Polyvisol liquid vitamins, and 1 ml of 10% formalin as a spoilage retardant. Both food sources were presented to all subjects because pilot studies contrasted with work from other laboratories (e.g.,[15]) in that rats with exclusive access to the liquid diet exhibited diarrhea and a tendency to gain weight at a slower rate. Subjects had one week to adapt to the new fluid; and then two days before injections, both water and liquid diet were removed from the cages of NW-48 subjects. One day before, the same procedure was followed with the NW-24 group. Only the liquid diet was made available during the testing trials, and W-0 rats were also presented with water. Care was taken to insure that the liquid diet was at room temperature. As before, half of each group received 2DG or physiological saline during the first session; and a reversal of this condition followed one week later. Ad lib water, liquid diet, and pellets were presented during the interval between sessions when water deprivation procedures were not in effect.

All food consumption measures were converted into kcal values, and eating measures during the lab chow and the liquid diet procedures were analyzed separately. For each type of food, cumulative eating was examined first with 4 (Group) ×2 (Injection) ANOVAs at each time interval. Intakes per each hour were also analyzed with a 4 (Group) × 2 (Injection) × 4 (Time Interval) ANOVA. Groups served as between-subject factor in these analyses while the other variables were within-subject factors.

RESULTS AND DISCUSSION

Cumulative pellet consumption is reviewed in the first half of Table 1. At each treatment interval, 2DG increased

TABLE 2

CUMULATIVE FOOD INTAKE (MEAN KCAL ± S.E.M.) AFTER 2DG AND CONTROL (CON) INJECTIONS IN 12-HR FASTED RATS GIVEN ACCESS TO LIQUID DIET OR PELLETS

			Intake At Intervals (Min) After Presentation of Food							
Group	Injection		15	30	60	120	180	240	300	360
Liquid Diet	2DG	Mean	5.28	9.90	16.94	21.56	25.08	29.04	30.69	32.12
		S.E.M.	2.32	2.72	2.81	4.42	3.20	3.78	3.65	3.86
	Con	Mean	13.09	15.51	18.37	21.34	22.88	24.09	26.40	28.49
		S.E.M.	2.33	2.31	2.06	2.12	2.36	2.39	2.94	3.02
Pellet Diet	2DG	Mean	7.44	10.24	13.59	20.29	25.27	27.55	31.04	33.75
		S.E.M.	1.04	1.14	1.17	1.57	1.84	1.49	1.88	1.89
	Con	Mean	12.53	14.80	17.23	20.05	21.63	26.49	29.20	32.30
		S.E.M.	0.97	1.16	1.80	2.34	2.29	3.19	3.47	3.65

feeding, F's(1,28)$\geq$6.73, p's$\leq$0.015; and Group differences appeared during the last two hours, F's(3,28)$\geq$4.31, p's $\leq$0.013. Most noteworthy, however, were the significant Group × Injection effects during these final two measurement intervals, F's(3,28)$\geq$3.83, p's$\leq$0.02. Post hoc tests (Newman-Keuls, $p<0.05$) revealed that these occurred because all three NW groups ate less than controls after 2DG but not after physiological saline. Basically, these results show that rats deprived of water under these particular procedures can eat more after 2DG, but the absolute magnitude of the increase is depressed. Mean pellet intakes per hour can be derived from Table 1, and these data are not presented separately for the sake of economy. The 4×2×4 ANOVA indicated that the W-0 rats ate more than the NW groups, $F(3,28)=5.21$, $p<0.01$, and that 2DG increased food consumption, $F(1,28)=34.23$, $p<0.001$. No other main or interaction effects were statistically significant. Finally, the W-0 Group drank significantly more after 2DG (10.9±0.9 ml) than after saline [2.9±0.6 ml: $t(7)=10.27$, $p<0.001$].

The second half of Table 1 presents the cumulative liquid diet results. Throughout, NW groups ingested more than the W-0 subjects, F's(3,28)$\geq$7.77, p's$<$0.001, an effect presumably reflecting their hydrational needs. A significant drug effect appeared only during the first hour when 2DG produced *lowered* consumption, $F(1,28)=23.86$, $p<0.001$; and a Group × Injection effect was evident during the last hour, $F(3,28)=3.23$, $p<0.05$. This interaction occurred because W-0 animals drank less than the other three groups after control injections but not after 2DG. Analysis of the mean intakes per hour again indicated that the W-0 animals generally consumed less, $F(3,28)=9.43$, $p<0.001$, and that the greatest consumption amounts occurred early in the session [Time effect: $F(3,84)=39.26$, $p<0.001$], particularly in NW animals [Group × Time: $F(9,84)=3.14$, $p<0.01$]. While 2DG had no overall effect, the drug produced an initial inhibition and subsequent facilitation of drinking [Injection × Time: $F(3,84)=14.65$, $p<0.001$] and also tended to elevate W-0 intakes and to depress those of NW-24 and NW-48 rats [Group × Injection: $F(3,28)=3.08$, $p<0.05$]. Finally, W-0 water intake (means$\leq$4.9 ml) remained uninfluenced by the drug when the liquid diet was available.

Results of this experiment revealed that post-2DG feeding patterns vary as a function of the diet presented. While eventually increasing their pellet intake after drug treatment, water deprived animals did not drink more liquid diet after 2DG; and instead they actually displayed an initial drug-induced inhibition effect. Why this latter effect occurred needs to be explained, but a clear possibility is suggested by the recent report that hypothermia accompanying 2DG treatment retards the ingestion of fluids which could serve as a further challenge to body temperature [10].

EXPERIMENT 2

When compared to control injections, 2DG treatment in neurologically intact, food deprived rats inhibits the consumption of a powdered laboratory chow, ([7], experiment 2). The purpose of the second experiment was to determine if a similar effect occurs when a liquid diet is made available.

METHOD

Subjects

Experimentally naive adult male Long Evans hooded rats served as subjects. These 20 animals weighed 333.2±9.1 g (mean±S.E.M.) at the start of the experiment and again were obtained from the departmental colony.

Procedure

Two equal sized groups (N=10) were formed through random assignment. Except during testing sessions, subjects in both the Pellet Diet (PD) and the Liquid Diet (LD) groups were given continuous access to Purina Lab Chow and to the liquid diet. Water was available ad lib to both groups throughout all conditions.

Testing procedures did not begin until rats had received one week of experience with their new diet. Animals were then familiarized with the experimental regimen through IP injections of physiological saline on three consecutive days. At lights-off on the night preceding the first formal trials, all food supplies were removed from the home cage; and twelve hours later, half of each group again received a physiological saline injection while the other half was treated with 250 mg/kg 2DG (Sigma Co., 10% w/v in distilled water), the dosage level reported by Larue-Achagiotis and LeMagnen [7] to inhibit eating in fasted animals. Approximately 10 minutes elapsed between the last injection and the presentation of food to insure that the drug had time to take effect before

TABLE 3

CUMULATIVE FOOD INTAKE (MEAN KCAL ± S.E.M.) AND WATER INTAKE (MEAN ML ± S.E.M.) AFTER 2DG AND CONTROL INJECTIONS IN RATS GIVEN ACCESS TO LIQUID DIET OR PELLETS

		Cumulative Food Intake			Water Intake	
		Hours Post-Injection				
Group	Injection	1	6	24	After 6 Hours	Next 18 Hours
Liquid Diet	2DG	3.62 ± 1.18	24.09 ± 3.05	82.72 ± 3.52	4.9 ± 1.0	9.0 ± 1.9
	Control	3.20 ± 1.18	8.15 ± 2.67	80.75 ± 5.62	4.5 ± 0.5	6.7 ± 1.8
Pellet Diet	2DG	5.33 ± 0.77	20.69 ± 2.40	89.88 ± 5.78	19.0 ± 2.1	35.6 ± 2.5
	Control	1.23 ± 0.57	7.79 ± 1.81	96.79 ± 5.31	9.6 ± 1.6	43.7 ± 1.6

feeding could begin. The LD rats were then presented with only the liquid diet while controls were given only lab chow pellets. Food intakes were monitored at 15, 30, 60, 120, 180, 240, 300, and 360 minutes after the presentation of food; and water intake across the entire six-hour interval was also recorded. One week later, these procedures were repeated, but with the injection condition reversed for each animal. All other procedures were essentially like those of the first experiment.

Data analysis first focussed on group cumulative food intakes and employed separate 2 (Diet) × 2 (Injection) ANOVAs at each measurement interval. Diet served as a between-subject factor, and the drug treatment operated as a within-subject variable. Again, all food consumption was expressed in kcal values. Intakes rather than cumulative intakes were analyzed with a 2 (Diet) × 2 (Injection) × 8 (Time Interval) ANOVA; and the Time factor was as a second within-subject variable. Finally, full session water intakes were also analyzed using a 2 (Diet) × 2 (Injection) ANOVA.

RESULTS AND DISCUSSION

Cumulative food intakes during the 6-hr experimental procedures are summarized in Table 2. The ANOVAs revealed that neither the Diet main effect nor the Diet × Injection interaction reached conventional levels of significance at any time period [all F's(1,18)$\leq$1.01, all p's $\geq$0.33]. A significant 2DG-induced suppression of feeding was evident for the first half hour, F's$\geq$6.92, p's$<$0.025; but thereafter, no Injection effects were evident, F's(1,18)$\leq$3.50, p's $\geq$0.08.

The 2×2×8 ANOVA for the raw intake values revealed that only the Time effect, $F(7,126)=12.36$, $p<0.001$, and Injection × Time interaction, $F(7,126)=5.10$, $p<0.001$, were statistically reliable. Clarification of this significant interaction involved use of correlated t-tests at each time interval to compare total sample eating after 2DG and with that after physiological saline. These data indicated that the drug inhibited eating at the 15 minute interval while elevating it at the 120 minute interval. Thus, the initial suppression was compensated for by a subsequent facilitation; and overall, results of this second study suggested that the reaction of fasted subjects to 2DG was largely unaffected by the type of diet presented.

Experimentals drank 3.8±0.7 ml of water after 2DG and 2.5±0.8 ml after saline while for PD rats these measures were 21.5±2.6 ml and 20.0±2.5 ml respectively. These drinking results revealed that LD animals consumed less water, $F(1,18)=21.17$, $p<0.001$, but neither the Drug nor the Diet × Drug interaction effects proved to be reliable, both F's $\leq$1.19, p's$\geq$0.29.

In some studies, injections of 2DG at night inhibit intake while those during the day exert a facilitating influence [7]. Like the present investigation, a number of unreported preliminary studies conducted in this laboratory, using a range of 2DG dosages, uncovered only a temporary drug-induced suppression of feeding in hungry animals; and not all researchers have observed the post-2DG nocturnal inhibition effect (e.g., [2]). Species differences exist in reactivity to 2DG [11], and perhaps strain characteristics are important too. It also may be noteworthy that 2DG depresses drinking in water-deprived subjects with a time course very much like that reported here for feeding in food-deprived rats (manuscript in preparation). Parallel effects in hungry and thirsty animals suggest the operation of a more general process not necessarily related to glucoprivation, perhaps one having to do with malaise.

EXPERIMENT 3

Increased eating after high doses of 2DG gives way to a delayed hypophagia so severe that 24-hour consumption after drug treatment is actually less than that observed in the 24 hours after control injections [15,16]. The purpose of this second study was to determine if a longer-term hypophagia would be evident in rats given access to the liquid diet.

METHOD

Subjects

The 20 rats used in the second experiment once again served as subjects.

Procedure

The third study began one week after the second one. All subjects continued to have ad lib access to water, the liquid diet, and lab chow; and one hour prior to experimental trials, fresh supplies of both diets were made available to ensure complete and equal satiation across the two groups at the start of observations. During the first session, half of each group received 750 mg/kg 2DG with other half injected with physiological saline. One week later these conditions were reversed. As before, LD subjects were presented only with liquid and PD animals only with pellets during the formal testing procedures. Intakes of food were monitored at 1, 6, and 24 hours post-injection; and intakes of water were recorded at the 6 and 24 hour time periods. Cumulative food

intakes at each time interval and water consumption values were analyzed with separate 2 (Diet) × 2 (Injection) ANOVAs with Diet as the between-subject and with Injections as within-subject variable.

RESULTS AND DISCUSSION

Table 3 summarizes the results of this final study, and analysis of the cumulative food intakes at the first two measurement intervals revealed a drug-induced enhancement of feeding [Fs(1,18)$\geq$4.85, p's $\leq$0.05]. However, neither the Diet, F's$\leq$0.54, p's$\geq$0.47, nor the Diet × Injection interaction [F's (1,18)$\leq$3.15, p's$\geq$0.09] proved to be reliable.

The ANOVA for the 24-hr data revealed a near significant tendency for the LD subjects to consume fewer calories than those in the PD group, $F(1,18)=3.82$, $p=0.066$. Again, this observation was consistent with pilot work in which animals with exclusive access to the liquid diet gained weight at a slower rate; and this effect, which contrasts with previous reports (e.g., 14), may be further evidence that rats from different laboratories vary in their reactions to supposedly more palatable foodstuffs (e.g., [1]). More importantly, the ANOVA also indicated that neither the Injection effect, $F(1,18)=0.66$, $p>0.50$, nor the Diet × Injection interaction, $F(1,18)=1.83$, $p=0.193$, were significant. The longer term, drug-induced hypophagia therefore was not replicated. A separate analysis of the PD 24-hr intakes revealed a post-2DG suppression of eating that would be significant only with a one-tailed test, $t(9)=1.87$, $p=0.095$, two-tailed test. No such tendency was evident in the LD results, $t(9)=0.33$, $p=0.75$.

Water intakes during the first six and then the next 18 hours were significantly less in the LD group [F's(1,18)$\geq$64.20, p's$<$0.001]. The first 6-hr drug-induced facilitation of drinking, $F(1,18)=8.90$, $p<0.001$, appeared to be an exclusive effect of the interaction between the diet and injection conditions, $F(1,18)=7.51$, $p<0.001$, since this increase was reliable only for the PD animals, $t(9)=3.06$, $p<0.05$. Similarly, during the next 18 hours, the lower water consumption after 2DG, $F(1,18)=4.52$, $p<0.05$, was due to the interaction effect, $F(1,18)=17.41$, $p<0.001$, because only PD animals displayed a depression, $t(9)=-4.87$, $p<0.001$. Further examination of the PD drinking data revealed that 2DG failed to influence 24-hr intake totals, fluid/food ratios (ml/kcal) during the final 18 hr, and fluid/food ratios for the total session [t's(9)$\leq$1.16, p's $\geq$ 0.14].

The results fo this final experiment most importantly questioned the robustness of the longer-term, 2DG hypophagia effect. The same basic pattern appeared in a number of preliminary studies conducted in this laboratory; so, the present data are supported by a number of previous observations. Contrasts in the dosage necessary to produce the delayed effect have been noted previously [15] and may explain the present discrepancy. The PD animals did exhibit a tendency toward hypophagia, but no such effect was evident in the LD rats. The possibility that the hypophagia is diet specific may therefore deserve additional research consideration.

GENERAL DISCUSSION

This investigation demonstrated that a liquid diet does not universally facilitate 2DG-elicited feeding during treatments that work against maximal glucoprivic responsivity. In fact, water deprived rats in the first experiment were unable to increase liquid diet consumption after drug injections. In the second experiment, food deprived animals responded to 2DG with the same basic feeding pattern regardless of the diet made available. Only in the third study did the liquid diet tend to moderate a longer-term, drug-induced tendency toward hypophagia; however, this hypophagia was only marginally apparent in animals presented with lab chow pellets.

Similar inhibitions of ingestive behavior followed 2DG treatment in the first two studies. In the intervals immediately after the drug injections, water deprived rats drank less liquid diet; and food deprived animals consumed less of both foodstuffs. These deprivation conditions resulted in high levels of consummatory activity with which 2DG treatment apparently was incompatible. Numerous other effects including ataxia and malaise [15] accompany drug-induced glucoprivation; and such influences may have produced the observed pattern. Again, malaise effects may be particularly noteworthy, especially since abnormal internal states produced by deprivation could interact with the drug treatment.

These data reveal that the liquid diet facilitation of 2DG-induced eating is at least somewhat specific to brain damaged animals. It has been suggested that the water intake deficits typically accompanying such lesions interfere with glucoprivic feeding and that the diminished hydrational challenge of the liquid diet disinhibits responding [19]. Indeed, the last two experiments demonstrated that LD animals drank less water than did PD subjects. In the first two studies, however, the liquid diet did not facilitate glucoprivic feeding in water and food deprived animals; and therefore, the less severe hydrational demand of this foodstuff was not a sufficient condition for promoting glucoprivic feeding. The relevance of the hydrational variable may therefore be questioned. Nevertheless, attempts to explain liquid diet effects in terms of palatability are framed within the context of other clear contrasts with lab chow pellets; and additional analyses of 2DG and dietary interactions may prove useful in clarifying the brain lesion literature.

REFERENCES

1. Bellush, L. L. and N. Rowland. Preference for high carbohydrate over various high fat diets by diabetic rats. *Physiol Behav* **35:** 319–327, 1985.
2. Booth, D. A. Modulation of the feeding response to peripheral insulin, 2-deoxyglucose or 3-*O*-Methyl Glucose Injection. *Physiol Behav* **8:** 1069–1076, 1972.
3. Dalton, L. D. and S. P. Grossman. Responses to dietary alterations in rats with zona incerta lesions. *Physiol Behav* **29:** 51–60, 1982.
4. Epstein, A. N. The lateral hypothalamic syndrome: Its implications for the physiological psychology of hunger and thirst. In: *Progess in Physiological Psychology*, vol 4, edited by E. Stellar and J. M. Sprague. New York: Academic Press, 1971, pp. 263–317.
5. Kanarek, R. B. and J. Mayer. 2-deoxy-D-glucose induced feeding: Relation to diet palatability. *Pharmacol Biochem Behav* **8:** 615–617, 1978.

6. Kanarek, R. B., M. Salomon and A. Khadivi. Rats with lateral hypothalamic lesions do eat following acute cellular glucoprivation. *Am J Physiol* **241:** R362–R369, 1981.
7. Larue-Achagiotis, C. and J. Le Magnen. Dual effects of 2-deoxy-D-glucose on food intake in the rat: Inhibition at night and stimulation in the daytime. *Physiol Behav* **23:** 865–869, 1979.
8. Le Magnen, J. The metabolic basis of dual periodicity of feeding in rats. *Behav Brain Sci* **4:** 561–575, 1981.
9. Marshall, J. F., J. S. Richardson and P. Teitelbaum. Nigrostriatal bundle damage and the lateral hypothalamic syndrome. *J Comp Physiol Psychol* **87:** 808–830, 1974.
10. Penicaud, L., D. A. Thompson and J. Le Magnen. Effects of 2-deoxy-D-glucose on food and water intake and body temperature in rats. *Physiol Behav* **36:** 431–435, 1986.
11. Rowland, N. Physiological and behavioral responses to glucoprivation in the golden hamster. *Physiol Behav* **30:** 734–747, 1983.
12. Smith, G. P. and A. N. Epstein. Increased feeding in response to decreased glucose utilization in the rat and monkey. *Am J Physiol* **217:** 1083–1087, 1969.
13. Stricker, E. M., M. I. Friedman and M. J. Zigmond. Glucoregulatory feeding by rats after intraventricular 6-hydroxydopamine or lateral hypothalamic lesions. *Science* **189:** 895–897, 1975.
14. Tepper, B. J. and R. B. Kanarek. 2-DG-induced glucopenia does elicit feeding in rats with lesions of the zona incerta. *Physiol Behav* **32:** 441–446, 1984.
15. Thompson, C. I. and I. S. Zagon. 2-Deoxy-D-glucose produces delayed hypophagia and conditioned taste aversion in rats. *Physiol Behav* **27:** 1001–1004, 1981.
16. Thompson, C. I., I. S. Zagon and P. J. McLaughlin. Hypophagia follows the initial hyperphagia produced by 2-deoxy-D-glucose in rats. *Physiol Behav* **23:** 187–190, 1979.
17. Vasselli, J. R. and A. Sclafani. Hyperreactivity to aversive diets in rats produced by injections of insulin or Tolbutamide, but not by food deprivation. *Physiol Behav* **23:** 557–567, 1979.
18. Walsh, L. L. and S. P. Grossman. Loss of feeding in response to 2-deoxy-D-glucose but not insulin after zona incerta lesions in the rat. *Physiol Behav* **15:** 481–485, 1975.
19. Watson, P. J. and M. D. Biderman. Failure of rats deprived of water to increase food intake during glucoprivation induced by 2-deoxy-D-glucose. *Pharmacol Biochem Behav* **17:** 955–959, 1982.
20. Watson, P. J., S. Beatey, M. D. Biderman and M. L. Pierce. Inhibited drinking and reduced glucoprivic feeding after 2-deoxy-D-glucose in rats adapted to quinine adulterated water. *Bull Psychonom Sci* **23:** 81–83, 1985.
21. Wayner, M. J., A. Cott, J. Millner and R. Tartaglione. Loss of 2-deoxy-D-glucose induced eating in recovered lateral rats. *Physiol Behav* **7:** 881–884, 1971.