Volume and Turnover of Body Water in *Dipodomys deserti* with Tritiated Water.* (25708)

C. R. RICHMOND, T. T. TRUJILLO AND D. W. MARTIN (Introduced by I. U. Boone)
Los Alamos Scientific Lab., University of California, Los Alamos, N. Mex.

The Kangaroo rat is of interest to the physiologist because of its rather unique water and electrolyte metabolism. That these animals can exist in xeric habitats, where cacti and succulent vegetation are not available as water sources, is well documented(1,2). If humidity and temperature are controlled, Kangaroo rats can be maintained in positive water balance when fed only dry seeds(2,3). No specialized water depots are known to exist in desert rodents(2,4). Although glomerular filtration rate, kidney size, and number of nephra are essentially the same as in other rats of similar weight(5,6), it is known that the structure of collecting ducts and papilla renis of Heteromyidae is unique among rodents(5, 7). Ames and Van Dyke(8) found high concentrations of antidiuretic hormone in urine and posterior pituitary of the Kangaroo rat. Howell and Gersh(1) suggested that absorption of water from the bladder may also occur; however, this mechanism could not be verified by other investigators(4). Higher concentrations of electrolytes in urine(9) and greater reabsorption of water from tubuli of Heteromyidae, as compared with the white rat(10), also have been demonstrated. One of the results of preceding mechanisms, which contributes to unique water economy of this animal, is that of a prolonged body water turnover time. However, comparatively little is known about the kinetics of water metabolism in the desert rat. Our purpose was to determine volume and turnover of exchangeable body water (using tritium water dilution method) as adjunct to a study of interspecific relations in water metabolism.

Materials and methods. The animals (*Dipodomys deserti*) were live-trapped in the Nevada desert,† and morphological characters were used to identify the species. Animals were housed individually in small galvanized sheet-metal cages containing dusty Nevada sand and covered with hardware cloth. Animal room was darkened and relative humidity maintained at 20-30% at 70-75°F. During 18-day acclimatization period, the animals were given pearled barley *ad lib.* and only an occasional slice of apple to serve as exogenous source of water. Pearled barley, which offers several advantages as food source, was kept in open container to assure equilibration of preformed water (*i.e.,* that water which can be removed by drying at 105°C) with the water in air. Two experiments were performed to determine turnover of exchangeable body water. The first (Group A) started after initial 18-day acclimatization, and the second (Group B) began about 80 days later following additional 14-day acclimatization in different animal quarters. Temperature in latter quarters ranged between 70-75°F, and relative humidity 10-20%. Each rat was injected intraperitoneally with 0.1 ml water containing 0.85 mc of tritium as HTO. At 2, 3, and 4 hours after injection, 0.02 ml of blood was drawn into a Sahli hemoglobin pipette from small incision in tail vein and mixed with 1 ml of normal saline. After centrifuging, 0.5 ml of clear supernatant was assayed for tritium activity using a liquid scintillation method. Details of assay procedure have been reported by Langham *et al.*(11). Tritium activity of each sample was converted to μc/ml of body water by multiplying by appropriate dilution factors and assuming blood to be 79% water. Equilibration of HTO with body water was determined from 3 blood samples obtained on first day, and turnover was calculated from changes in HTO concentration in 5 blood samples obtained for 18-day period.

Results. The mean exchangeable body water content for 20 animals was 62.37% of body weight, with standard deviation (σ) 2.16. No

* Work performed under auspices of U. S. Atomic Energy Comm.

† We acknowledge our appreciation to Dr. Kermit Larsen of Environmental Radiation Division, Univ. of California at Los Angeles, for these animals.

TABLE I. Mean Exchangeable Body Water Content of *Dipodomys deserti*.

Group	No. of animals	Mean body water content (% of body wt)
A	8	62.00 ± 2.17*
B	12	62.63 ± 2.21
Total	20	62.37 ± 2.16

* $\sigma = \pm \sqrt{\frac{\Sigma x^2 - \Sigma x\,(\bar{x})}{n-1}}$.

statistically significant difference between mean exchangeable body water content of the 2 groups was observed (Table I), and the turnover of HTO followed a single exponential function throughout experimental period (Fig. 1). The half-time ($T_{½}$) of body water turnover of each group can be determined from the relationship $T_{½} = \frac{0.693}{k}$, where k is the rate constant. The mean life (τ) of HTO in each group is equal to reciprocal of rate constant. Table II lists values of parameters a and k of the exponential rate equations and $T_{½}$ for individual animals. Values for a and k were obtained from regression equations calculated by the method of least squares.

Water intake for animals in Group A was estimated from food consumption and compared with the value calculated from exchangeable body water and turnover data shown in Table II and Fig. 1. Mean exchangeable body water content at time zero is the product of body weight and the fraction of body weight which is water (59.41 g water). As loss is exponential, the amount remaining in the body at end of first day (A_1) can be calculated from the following relationship (where A_0 is equal to 59.41 g, and t is equal to 1 day): $A_1 = A_0e^{-kt} = 55.23$ g water. The difference between A_0 and A_1 is equal to loss during first 24 hours, which amounts to about 4.2 g water.

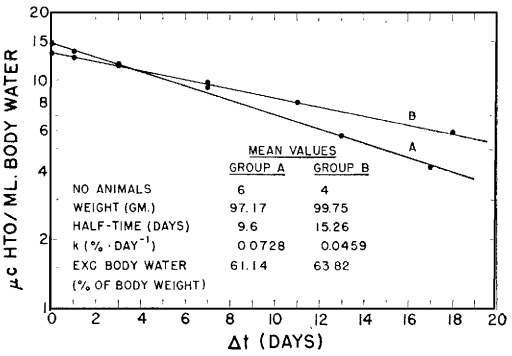

FIG. 1. Change in body water HTO activity in *Dipodomys deserti* as a function of time.

Each 100 g of barley (dry weight) consumed by animals gave rise to 54 g of water *via* biological oxidation of hydrogen(12). The preformed water content of barley available to rats in Group A was approximately 10%. From average food intake for 14 days period, average total daily water intake was 3.9 g/rat. Average daily water intake of animals in Group B (calculated from exchangeable body water and turnover data) was 2.9 g.

Discussion. The value obtained for body water content of *Dipodomys deserti* is in fair agreement with that determined by drying entire animal(2). In a group of 23 animals maintained on dry food only, body water ranged from 62-70% body weight, with a mean of 66% as compared with 62% in our study. This small difference is probably not due to variation in species, since similar values were obtained for *Dipodomys spectabilis* and *Perognathus baileyi* (pocket mouse), which are also members of the family Heteromyidae (2). These investigators found no significant difference between percentage of body water in rats maintained on dry food and on diets of varying water content.

TABLE II. Individual Values of Parameters of the Water Retention Function.*

Group	Wt (g)	Retention of body water a	k	$T_{½}$ (days)
A	95	14.79	.06376	10.87
	93	14.50	.06637	10.44
	111	13.09	.08183	8.47
	82	17.61	.06746	10.27
	102	14.03	.07719	8.98
	100	14.20	.08002	8.66
Mean	97.17	14.70	.07278	9.62
B	105	12.14	.04536	15.29
	76	17.30	.04485	15.45
	112	11.73	.04816	14.39
	106	12.32	.04508	15.37
Mean	99.75	13.38	.04586	15.13

* $A_t = ae^{-kt}$, where A_t is HTO activity (μc/ml) of body water at any time t; a is HTO activity (μc/ml) of body water at time zero; k is fractional change/day; and t is time in days.

Newly captured animals appear to have a

higher percentage of body water than animals in captivity for longer times(2). Captive animals apparently become fatter and less muscular, and amount of body water relative to body weight decreases because fat contains less water than muscle. No statistically significant difference was found between exchangeable body water content of the 2 groups of animals in this investigation, even though determinations were made about 18 and 100 days after their arrival from the desert. The different conditions of relative humidity to which each group was exposed, however, might justifiably preclude any comparison of body water content as a function of time in captivity.

The 10- to 15-day half-time for HTO in the Kangaroo rat is extremely long, as compared with the white rat, which has a half-time of about 4 days. It is interesting also that water retention half-time of the Kangaroo rat (maintained on diet of pearled barley only) is longer than that of the dog, monkey, and man on *ad lib.* water intake. A statistically significant difference ($p = < 0.01$) between mean half-time for each group appears real, in spite of the small numbers of animals. It has been shown by Schmidt-Nielsen *et al.*(3) that there exists a lower limit of relative humidity and temperature (about 10% relative humidity at 75°F) beyond which these animals cannot remain in positive water balance when maintained on a dry diet. The animals in Group B were exposed to very similar conditions, and their increased water retention might represent a response to one or more environmental changes such as light, noise, relative humidity, or time in captivity. The results of this investigation demonstrate the effectiveness with which the Kangaroo rat conserves water and thereby survives in a xeric environment.

Summary. Mean exchangeable body water content ($\pm \sigma$), as measured by the tritium water dilution method, was 62.37 $\pm$ 2.16% of the body weight for 20 Kangaroo rats (*D. deserti*). When maintained on a diet of pearled barley only, 2 groups of animals showed mean turnover times for exchangeable body water of 13.9 and 22.1 days. This is much longer than that found in the ordinary white rat and in other mammals and presents an adaptation to a xeric environment.

1. Howell, A. B., Gersh, I., *J. Mammal.*, 1935, v16, 1.

2. Schmidt-Nielsen, B., Schmidt-Nielsen, K., Brokaw, A., Schneiderman, H., *J. Cell. Comp. Anat.*, 1948, v32, 331.

3. Schmidt-Nielsen, B., Schmidt-Nielsen, K., *J. Cell Comp. Physiol.*, 1951, v38, 165.

4. ———, *Physiol. Rev.*, 1952, v32, 135.

5. Rytand, D. A., *Am. J. Anat.*, 1938, v62, 507.

6. Schmidt-Nielsen, B., *Am. J. Physiol.*, 1952, v170, 45.

7. Vimtrup, B., Schmidt-Nielsen, B., *Anat. Rec.*, 1952, v114, 515.

8. Ames, R. G., Van Dyke, H. B., PROC. SOC. EXP. BIOL. AND MED., 1950, v75, 417.

9. Schmidt-Nielsen, K., Schmidt-Nielsen, B., Schneiderman, H., *Am. J. Physiol.*, 1948, v154, 163.

10. Schmidt-Nielsen, B., *Fed. Proc.*, 1950, v9, 113.

11. Langham, W. H., Eversole, W. J., Hayes, F. N., Trujillo, T. T., *J. Lab. Clin. Med.*, 1956, v47, 819.

12. Schmidt-Nielsen, K., Schmidt-Nielsen, B., *Sci. Am.*, 1953, v189, 73.

Received September 8, 1959. P.S.E.B.M., 1960, v104.