WATER BALANCE IN THE MULGARA (*DASYCERCUS CRISTICAUDA*), A CARNIVOROUS DESERT MARSUPIAL

By K. Schmidt-Nielsen* and A. E. Newsome†

Summary

A small Australian marsupial, the mulgara or crest-tailed marsupial-mouse (*Dasycercus cristicauda* Krefft), lives on a predominantly or exclusively carnivorous diet. It inhabits the most arid part of central Australia where the average rainfall is 5–10 in. per year. In the laboratory and in the absence of heat stress, the animal can maintain or gain weight without drinking water on a diet of whole mice or fresh lean meat. Its kidney can produce a urine highly concentrated with respect to urea, and the large amounts of urea formed on a carnivorous diet can therefore be excreted in a relatively small volume of urine. This desert animal can therefore subsist on the water contained in its food without drinking free water or eating succulent plant material.

I. Introduction

Many animals with carnivorous food habits, including true carnivores, insectivores, and rodents, live in deserts where no drinking water is available, and it is obvious that their needs for water must be covered in some other manner. It has generally been assumed that these desert animals obtain sufficient free water with their food to provide an ample supply for physiological needs. Since very little attention has been given to desert animals with carnivorous habits, we found it of interest to carry out some preliminary experiments with a carnivorous marsupial, the mulgara or crest-tailed marsupial-mouse (*Dasycercus cristicauda* Krefft). Sufficient water to cover the physiological needs for urine excretion, evaporation, and formation of faeces could be obtained either (1) from the body water of the prey or (2) from some other source of water, such as green plants, etc. The experiments showed that the mulgara obtains sufficient water from, and remains in water balance on, a purely carnivorous diet.

II. Material and Methods

The mulgara is a small marsupial with an adult body weight of 50–100 g. It is a typical inhabitant of inland Australia where it is one of the commonest small mammals, even in the most arid areas. Its dentition is insectivorous and its food habits are assumed to be characteristically carnivorous, with insects, small reptiles, and small rodents as major dietary components (Jones 1923). In captivity such food is eaten readily. In nature availability undoubtedly plays a major role in the relative importance of these food items.

Our animals were dug out of burrows in sandy country covered by spinifex (*Triodia* spp.) at Yuendemu, 165 miles north-west of Alice Springs, and at Papunya,

* Department of Zoology, Duke University, Durham, N. Carolina.

† Animal Industry Branch, Northern Territory Administration, Alice Springs, N.T.

125 miles west of Alice Springs, central Australia. They were maintained individually in perforated cardboard cartons with sawdust bedding and with access to a small nest-box with cotton-wool as bedding. The animals were weighed accurately to 0·1 g on a Mettler balance. In some experiments they were fed freshly killed laboratory mice once a day, in other experiments fresh lean minced meat. Whole mice contain about 66–68% water, and samples of fresh minced meat similar to that fed to our animals contained 76% water and 17·5% protein. The amount of food consumed was determined by weighing the remaining parts. In the laboratory the animals were maintained at a room temperature of about 25–30°C. They were not exposed to severe heat stress during the period of the observations reported here.

Urine samples were obtained as they were voided spontaneously. The animal was lifted out of its nest-box and held over a glass plate which had been treated with silicone to render it water-repellent. Samples for analysis were taken immediately with a micropipette, and analysed for urea and total electrolyte contents. No measurable evaporation took place in the short time between the urination and the pipetting of the samples.

Urea and, in some cases, ammonia were determined according to the micro-diffusion method of Conway and O'Malley (1942). Known solutions of ammonium sulphate pipetted with the same micropipette served as analytical standards. The electrolyte content was measured by determining the electrolytic conductivity of 20-μl samples previously diluted to 1 ml. A cell with platinum electrodes and a Philips PR9500 Wheatstone bridge were used. All values for total electrolytes are expressed as the concentration of a sodium chloride solution with the equivalent electrolytic conductivity (Holm-Jensen 1947).

III. Results

(*a*) *Changes in Body Weight of Mulgaras on a Diet of Laboratory Mice*

A group of five mulgaras which had previously been fed on minced meat with drinking water available was placed on a diet of freshly killed mice. Each individual animal was given one freshly killed and weighed mouse in the evening, and the remaining parts were removed and weighed the following evening. The initial and final weights of each animal are listed in Table 1, both for this and the following experiment. In order to compare the individual animals their weight changes have been calculated as a percentage of their initial weights and plotted in Figure 1. After 6 days all the animals had gained weight and the average gain of the group was 11·1% of the initial body weight. The animals gave every evidence of being healthy and thriving, and they were obviously in water balance, for a negative water balance in animals of this size would manifest itself within a day or two as a considerable weight loss.

(*b*) *Weight Gain of Mulgaras on a Diet of Minced Beef*

A group of six mulgaras, which had previously been kept for several weeks on a diet of canned meat, occasional fresh meat, and free access to drinking water, was given a diet of fresh lean beef only, without drinking water. The preceding diet did not seem attractive to the animals, and when they were changed to the diet of fresh meat they rapidly gained in weight (Fig. 2).

In 4 days this group of animals gained an average of about one-third of their body weight, and they retained this weight gain over the succeeding 7 days. When weighed 4 weeks later, after having remained on the same diet of fresh meat, they had gained further and attained a mean weight of 57·6% above the initial weight. The initial rapid increase was apparently a compensation for the fact that the animals were somewhat starved on the preceding unpalatable diet. The continued gain in weight over the succeeding 5 weeks could partly be due to accumulation of fat and partly to growth (the animals were trapped in the wild and many were large young, still found associated with their mothers when captured a month before our experiments). In the larger animals the tail became very thick due to the characteristic

TABLE 1

WEIGHTS OF INDIVIDUAL MULGARAS FED WHOLE MICE OR LEAN MINCED BEEF WITHOUT DRINKING WATER

Diet: Whole Mice				Diet: Lean Minced Beef			
Mulgara No.	Initial Weight (g)	Weight after 6 Days (g)	Increase (%)	Mulgara No.	Initial Weight (g)	Weight after 11 Days (g)	Increase (%)
A	33·8	42·9	27·0	F	29·9	42·9	43·5
B	46·5	51·4	10·7	G	49·9	64·8	29·9
C	31·7	35·6	12·2	H	29·6	41·2	39·1
D	39·7	40·3	1·6	I	25·4	35·4	43·5
E	47·5	49·5	4·2	K	34·6	45·7	32·0
				L	24·6	30·6	24·8
Mean	39·8	43·9	11·1		32·3	43·4	35·5

deposition of fat in this species in the basal part of the tail. The ability to gain weight rapidly and to store large amounts of fat is of significance if food supply fluctuates in the wild, and a carnivore cannot store food the way some herbivores do. However, it is not understood whether any special significance can be attached to the location of stored fat specifically in the tail, a curious phenomenon which occurs also in several other small animals in the Old World and in American as well as Australian deserts.

It is evident from these observations that a pure meat diet is sufficient for maintaining mulgaras in water balance for indefinite periods. (It is, on the other hand, obvious that the experiments give little information as to the nutritional adequacy of the diet; long-term feeding experiments and the ability to reproduce would be necessary to establish nutritional quality of the diet. Subjectively, we gained the impression that individuals which fed on whole mice and ate viscera, bone, etc. were in better condition and had a smoother fur than animals fed on minced meat only.)

On the whole the animals consumed between 20 and 25% of their body weight per day. This amount of food is normal for an animal of the size of a mulgara when maintained in the laboratory.

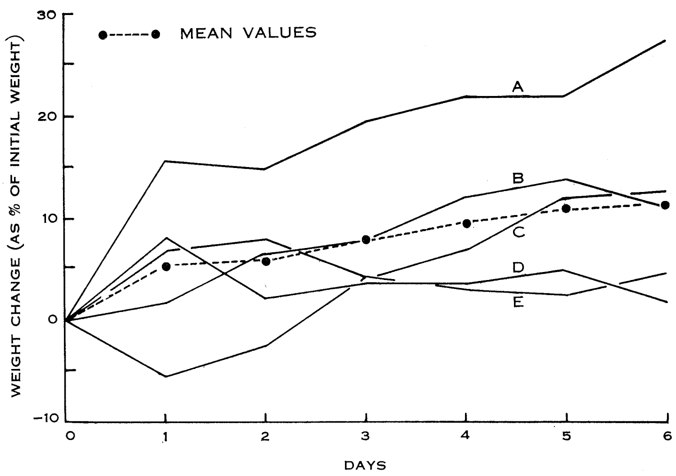

Fig. 1.—Daily weight changes in mulgaras fed freshly killed laboratory mice. Letters *A–E* refer to the same individual animals as in Table 1.

(*c*) *Urine Concentrations*

The two most important items of water expenditure are evaporation and urine production. We have not determined evaporation in mulgaras, but they were kept under conditions where active heat regulation by evaporation of water was unnecessary.

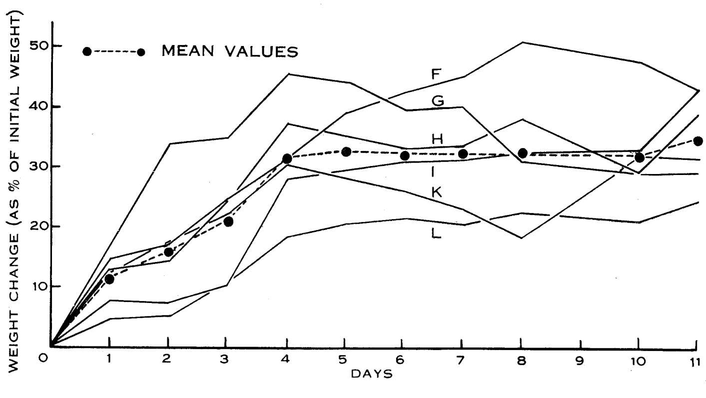

Fig. 2.—Daily weight changes in mulgaras fed fresh minced beef. Letters *F–L* refer to the same individual animals as in Table 1.

(It is doubtful whether an animal the size of a mulgara uses water for heat regulation since such small animals generally avoid heat exposure by remaining in subterranean burrows when ambient air temperatures are high (Schmidt-Nielsen 1954).) The other major source of water loss is the water required for urine formation. On a meat diet (high protein) the major excretory product is urea, which requires considerable amounts of water for excretion. The more concentrated the urine is, the less water is necessary for the elimination of a given amount of urea. Thus, the concentrating ability of the kidney becomes a primary factor in the water economy of an animal.

Determinations of the urea concentration in the urine of mulgaras showed that these animals have an unusual ability to produce a concentrated urine. Table 2 shows the concentration of urea and electrolytes in a series of urine samples from animals maintained on a meat diet without drinking water.

TABLE 2

CONCENTRATIONS OF UREA AND ELECTROLYTES IN URINE FROM MULGARAS FED ON WHOLE MICE OR LEAN MINCED BEEF, BUT WITH NO DRINKING WATER

Diet: Lean Minced Beef		Diet: Whole Mice	
Urea Concentration (m-moles/l)	Total Electrolytes* (m-equiv/l)	Urea Concentration (m-moles/l)	Total Electrolytes* (m-equiv/l)
840	192	1980	522
995	252	2260	546
1080	414	2350	564
1290	470	2420	525
1310	422	2430	548
1990	547	2590	475
2020	351	2610	674
2110	316		
2300	615		

* Expressed as the concentration of a sodium chloride solution with equivalent electrolytic conductivity.

All the samples contained urea in a high concentration, the values ranging between 840 and 2610 m-moles/l (5% and 15·6% urea, respectively). We do not know whether the highest values denotes the maximum concentration that can be reached, but it indicates that the kidney of the mulgara at least exceeds many other mammalian kidneys in its ability to excrete urea economically with respect to water.

The concentration of electrolytes in the urine is also quite high. The values range up to 674 m-equiv/l, which is somewhat higher than the concentration of sea-water (about 550 m-equiv/l). In man the maximum concentrating ability for electrolytes is about 370 m-equiv/l and in the white rat about 600 m-equiv/l. Since the mulgaras were not exposed to a high salt intake and apparently were not in particularly short supply of water, it is quite possible that the maximum concentrating ability of the kidney exceeds the values reported here. Its kidney has a long papilla which, as pointed out by Sperber (1944), is closely correlated with the need for water conservation.

IV. Discussion

The highest urea concentration observed in man is about 800 m-moles, in the white rat about 2200 m-moles, and in the cat about 2300 m-moles (Prentiss, Wolf, and Eddy 1959). Two excellent water conservers among desert rodents, the American kangaroo-rat (*Dipodomys merriami*) and the Old World jerboa (*Jaculus jaculus*) can reach much higher urea concentrations with limits of 3800 and 4200 m-moles/l, respectively. Thus, the renal concentrating ability of the mulgara exceeds that of the cat, which can subsist without water when fed on meat only, but may not equal the most efficient mammalian kidneys known. Whether the mulgara would produce a more concentrated urine under conditions of higher protein intake or urea load should be investigated.

One of the most quoted papers on water balance in a carnivorous animal is a study on the water balance in the seal (Irving, Fisher, and McIntosh 1935). This study showed that the seal, when eating a diet of herring, should have sufficient water available from the food and from oxidation of the foodstuffs to cover all needs for evaporation as well as formation of urine and faeces. An excellent study of the same problem in the cat has been carried out by Prentiss, Wolf, and Eddy (1959), who showed that the domestic cat is able to remain in water balance on a diet of fresh meat or fish. However, if the meat or fish is partly dehydrated by evaporation of water, the cat is unable to remain in water balance. It could therefore be expected that any carnivore with a renal concentrating ability comparable to that of the cat should be able to remain in water balance; and that desert carnivores in general should also be able to maintain water balance under similar conditions unless water is needed for heat regulation. In the event of heat stress, the amount of water used for evaporation will depend on the heat load, and the possibilities for an animal to remain in water balance would therefore also be related to the degree of heat stress. To the extent that desert carnivores hunt during the hot day, considerable demands are made on their water resources. Studies of animals such as the dingo (*Canis familiaris dingo*), the hunting dog (*Lycaon pictus*), and the jackal (*Canis aureus*) and others would probably yield very interesting information.

The mulgara has subterranean burrows and probably avoids heat stress by remaining underground when the outside temperature is high. The ability of the mulgara to remain in water balance on a meat diet and its ability to produce a highly concentrated urine shows that this animal is able to derive sufficient water for its normal physiological needs from a carnivorous diet. In the arid parts of central Australia where it lives the average annual rainfall is from 5 to 10 in. Free water exists only after rain and few succulent plants occur. The studies reported here indicate that it is unnecessary for the mulgara to supplement its water intake by drinking free water or by consumption of succulent plant material.

V. Acknowledgments

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