PATTERN OF NORMAL WATER DRINKING IN DOGS

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Intake of water is a discontinuous process; in contrast to output of water which is continuous, and ordinarily almost constant in rate from minute to minute. The discontinuity suggests that the water content of the body periodically becomes sensibly unbalanced, whereas the act of water drinking restores the body and relieves at once the maladjustment of content. What sort of signal initiates water drinking in hourly life? How regular are the periods at which it operates? What sorts of factors modify the periods?

One of nine trained dogs was put in a stall suspended from a Sauter balance. Most observations were made upon two females with exteriorized bladders. In periods of 0.25 hour the insensible loss of weight was ascertained. Urinary loss was found by measuring the urine collected from the exteriorized bladder each 0.25 hour. In most periods, drinking water was available in a can just in front of the dog. Whenever the dog took water, the can and its contents were reweighed. Room temperatures lay between 22° and 26°C. and relative humidities between 30 and 50 per cent.

In some tests the dog did not merely stand in the stall loosely confined, but heat was applied or food was given. Heat was added to the body by two radiators placed laterally at constant position and intensity. The intensity was chosen such that the dog did not fidget. Food consisted of dried whole milk and fox chow, usually mixed with an equal weight of water. The dog swallowed at once all of the food offered. On most days the food allowed each 24 hours was constant, the amount being sufficient for maintenance of body weight.

The Sauter balance was used in such a manner that exact equilibrium between its two sides was not required. One minute before the dog’s weight was to be ascertained, the balance was allowed to swing, with approximately correct weights in the pan. The midpoints of the free swings just before and just after zero time were averaged; and since the deflection per gram had been previously ascertained with the same dead loads on the balance, the weights in the pan could be corrected, to give an accuracy of weighing of 0.2 gram. Actually only the nearest 0.5 gram differences were ascertained, since these gave 6 per cent accuracy per 1-hour period at the slowest rate of insensible loss.

In each test the dog had been fed 16 hours previously and had been allowed water ad libitum. In addition, the dog was offered water upon coming to the stall; if it drank some, drinking to satisfaction was allowed and the test was started; but if it drank none, the dog was not considered to be in a reproducible state of water balance and no test was run upon it that day.

A. Control. When water was continuously available, rates of water loss be-
came stabilized about 1 hour after the dog was first weighed (fig. 1). In this period the animal "calmed down" and slight diuresis resulted from the water spontaneously drunk at zero time.

Water was voluntarily drunk in only one instance during ten control tests that lasted 2 hours, in which time 0.35 per cent of the body weight ($B_0$) had been lost ($A$, fig. 2). In the one instance 0.29 per cent of $B_0$ was drunk at 1.6 hours, just restoring the body weight. In two tests that lasted 4 hours, water was taken once at 3.7 hours to the amount of 0.40 per cent of $B_0$. During the 4 hours 0.60 per cent of $B_0$ had been lost.

The pattern of ordinary drinking is plain. The dog does not sip water at frequent intervals even though the water is immediately available, but waits some hours between drafts. The draft when taken is not sufficient to restore body weight, but may be considered sufficient to restore water content relative to the body's content of other substances.

B. No water; later allowed. When water was not allowed during the first 3 hours, weight was lost as before. Then water was placed before the dog, and in four of eight tests water was drunk within a few minutes. The amounts ingested varied only between 0.18 and 0.38 per cent of $B_0$, 0.50 per cent of $B_0$ having been lost. Comparison with the previous result possibly indicates that lack of availability of water tends to induce drinking more frequently when later the water is allowed. But in no case is the amount drunk sufficient to restore body weight.
On the average a loss of weight equal to 0.5 per cent of $B_0$ is required before drinking supervenes.

C. Control, then heat. In these four tests, water was available at all times. After 2 hours of control conditions, heat was applied for 1 hour, the rate of weight loss being greatly accelerated. In the last half of this hour, water was drunk in every instance, and in amounts not sufficient to restore the body weight. Again, 0.5 per cent of $B_0$ had been lost before drinking occurred (C, fig. 2).

Rectal temperatures fell during the control hours, rose about 0.8°C. during the heating, and fell during 1.3 hours thereafter. The drinking was not clearly related to any particular rise of body temperature.

D. Heat; water later. The same form of test was modified by denying the dog water during the heating and for 0.5 hour thereafter. Would the fact that heat no longer impinged on the body lessen the urge to take water? The answer was that just as much water was drunk as in C, in the four tests. Therefore, the heat does not exert its influence only immediately, but also latently. Altogether, heating was scarcely more efficacious than non-heating in induction of water ingestion, at the same deficit of body weight.

E. Initial heat; water later. Water was denied after the initial drink of the day. Without a previous control period, heat was applied for one hour (E, fig. 2). Then water was allowed, and in five of six tests was drunk within 0.5 hour. In this series 0.5 per cent of $B_0$ had been lost in 1 hour instead of 3 hours; no more water was taken here than there. It appears that time is a negligible variable; the amount of water missing from the body is the factor in common.

Summary. Dogs placed under control conditions with minimal physical activities, gradually lost weight by evaporation and by urine formation. Periodically these losses were partially made up by drinking. Drinking rarely occurred before 0.5 per cent of $B_0$ had been lost, and was insufficient to restore body weight. It occurred somewhat more surely when water had been previously denied the dog, and when the loss had been hastened by heating. The heating may have been over and gone before water was offered, yet drinking occurred more freely. The chief factor in inducing drinking appears to be the lack of body water and not the time that intervened during its loss.

F. Control with food. It is shown above that dogs which were fed many hours ago drink little water. This fact has long been recognized in that dogs drink only $\frac{1}{4}$ to $\frac{3}{4}$ as much water upon days when food is withheld as upon days of usual feeding.

In order to study the effects of eating upon drinking, food as well as water was given ad libitum at all hours. A popular notion is that dogs cannot be permitted unlimited food; the regime, however, proved satisfactory. The dogs ate somewhat more than was required for maintenance of weight, gaining about 0.5 per cent of $B_0$ per day on the average.

In these tests (32 days) two dogs remained in metabolism cages. All food and water present were automatically registered. Water level in the drinking pan was recorded as previously described (Adolph, 1939). Dry food was kept in a pan suspended from a spring within the dog's cage; a string from the pan to a
lever indicated the length of the spring and consequently the weight of the food remaining.

The food was taken in about five meals per day. No fixed hours were evident for these meals; but more than average occurred in late afternoon when the dogs were accustomed to being fed, and very few occurred late at night. Only rarely was food merely tasted; instead, eating continued for 5 minutes or more and a mode of 0.18 per cent of $B_0$ was swallowed at each occasion. Water was rarely drunk between bites, but usually was taken only after eating was finished, when modally 0.38 per cent of $B_0$ was ingested within 10 minutes. The pattern of water drinking therefore shadowed that of eating. Body weight was fully restored at most meal times. Hence, the periodic taking of food with water eliminated the trend of decrease in body weight that prevailed in the absence of food. Instead, ingestions, which voluntarily occurred every 4 to 6 hours, restored body weight and made it oscillate about a gradual upward trend.

G. Food at stated intervals. The relation of food intake to drinking was studied further by allowing portions of food at fixed intervals. Whereas the

![Fig. 3. Excesses of body weight of dogs, in per cent of initial weight, in tests G in which food was periodically given. The weight of food allowed is indicated by thickened lines; all other gains of weight were due to ingestion of water while losses were simultaneously proceeding at 0.08 to 0.20 per cent of $B_0$ per hour.]

whole amount of food had been given (in parts A to E) at 4 p.m., the amount was now divided into portions proportional to the period of time before the next meal.

(a) The dog was kept in the stall for 6 hours, having received $\frac{3}{4}$ of the ration 18 hours previously. In four tests the remaining $\frac{1}{4}$ of the food was mixed with an equal weight of water and given at once. On the average the dog drank water in each subsequent half-hour, and body weight increased further for 2 hours and then gradually declined (a, fig. 3). During the decline water was occasionally drunk in each test, but not in amounts sufficient to compensate the simultaneous losses.

This experiment indicates that the periodicities of body weight were chiefly controlled by the periodicities with which food was spontaneously taken by the dog. Although some water was drunk without food, more water was taken at each draft when food had preceded it.

(b) In three tests, $\frac{1}{4}$ of the food was given dry at the beginning of the test, and $\frac{1}{4}$ of it 3 hours later. Body weight increased with each meal, partly because water was ingested soon after it. Thus body weight oscillated in shorter periods.
(c) Finally, in four tests, \( \frac{1}{4} \) of the dry food was given each hour for 6 hours. Water was then drunk every hour, usually within 5 minutes after food was swallowed, and correspondingly body weight steadily increased (c, fig. 3). Somewhat more urine was produced in these tests.

Summary. It is evident that the pattern of food ingestion may dictate the pattern of water ingestion. The periods between water ingestion could be rendered so small that body weight increased steadily rather than in 6-hourly or in 21-hourly periods. Food ingestion obviated the rule that loss of weight preceded drinking. Rather, the proportion of solids to water within the body was modified by addition of the food instead of depletion of the water.

Comment. Drinking is a means of periodically restoring body water content. Previously (Adolph, 1939) it was found that the amounts drunk by the dog were equal to the amounts of water earlier lost from the body during water privation (which could be induced in one to several days while dry food was eaten). Now it is found that the smallest amount of water loss to which the dog usually responds is 0.5 per cent of the body weight. Not the time elapsed (which could be much reduced by heating the dog), but the shortage of water itself appears to set off ordinary drinking. And not the absolute amount of water but the decrement in the proportion of water to other bodily constituents (which could be varied by feeding the dog) seems to arouse the drinking.

These relations naturally result in the observed pattern of water ingestion of the dog. Ordinarily processes of anabolism and catabolism are producing slow changes in the proportions of bodily constituents. Whenever water is out of ratio by about –0.5 per cent of its usual content, a draft of it is taken, in approximately that amount. Usually less water is taken than has been lost since the last drink or meal.

This generalization pictures water content as continually in deficit. But since there is no base line from which to judge deficit other than the usual content of water in the body, it is merely for convenience of reference that water balance in these tests was considered to lie at the body weight of the dog that had just drunk water ad libitum. Obviously, too, body weight is but a rough criterion of water balance, since addition to the body of food and water in particular proportions increases the weight without destroying the immediate balance.

It was found that water was usually drunk a few minutes after dry food was eaten. Since the reverse rarely occurred, some support could be deduced for the notion that eating sets off drinking. If so, what releases the act of eating? With food continuously available, some cumulative influence periodically takes effect. To call that influence either hunger or appetite does not help to understand it. It is related to certain or all of the bodily deficits that gradually develop to some critical value before the trigger to eating is released.

The important point here is, however, that if the dog’s five meals a day are stopped by deprivation of food, drinking that ordinarily follows each meal goes on just the same. The amounts drunk are reduced, but the same number of drafts are taken per day. Hence the pattern of drinking is demonstrated to exist independently of eating, though ordinarily the two work together in one sequence. The fact that some water is drunk during the deprivation of food
may indicate that water lost by the quiet dog is in excess of the body water liberated from its connection with catabolized constituents of the body. The constancy of urinary composition opposes the view that much water is drunk in excess of needs under any circumstances.

While the above rules held for the dogs studied in the laboratory, it is quite probable that deviations from these rules with respect to certain details will be found in other individuals, and particularly in individuals not conditioned to laboratory existence.

The sensitivity of the dog to the deficit of water which leads to drinking is such that on the average the dog drinks when 0.5 per cent of the body weight has been lost. Whatever sense organs or nerves are sensitive to want of water, and initiate sensations of thirst, themselves set in motion the response of drinking at this deficit of water. The result is an oscillation of water content of the body through sudden periodic intakes. But if food were supplied continuously at a rate equal to catabolism, the fluctuations to either side of the mean would be expected to amount to only 0.25 per cent of the body weight.

It is noted that the dog does not take its water in as continuously as the frog does. No terrestrial animal does so. It is appropriate to point out that intermittency of an activity allows successions of activities that cannot be carried on simultaneously. With respect to water, the dog is able to spend 99 per cent of its time away from water, providing that water can be reached at appropriate intervals. An animal as large as the dog is able, in absence of marked physical activity, to be away from water for 4 to 6 hours without change of more than 1 per cent in its water content. Hence body fluids and cells are kept approximately that constant in composition in spite of the intermittent character of intakes of water and food.

The picture that we derive from the above observations is that 1, the state of water balance is continually changing in relation to body weight, according as other metabolic processes are active; 2, change in rates of catabolism or sudden addition of food or solute to the body shifts the state of water balance accordingly; 3, the actual content oscillates about the virtual content at which water is balanced; 4, the period of this oscillation varies with rates of water exchange; but 5, the amplitude of this oscillation is ordinarily quite constant, through the fact that the dog drinks whenever the deficit of water is great enough to arouse an effective thirst. Many details remain to be added to this general statement.

SUMMARY

The conditions of water loss and of food gain were varied while spontaneous drinking was observed in dogs. The signal that initiates water drinking in ordinary life appears to be a deficit of water relative to other bodily components. Whenever the body is depleted of water by about 0.5 per cent of the body weight, water is drunk. The amount drunk is accurately proportioned to the body's water deficit at each draft, though no absorption of water has time to occur before drinking ceases. Body weight is only a rough criterion of water balance, even under restricted circumstances, since addition of food and loss of catabolic products complicate its relations.

REFERENCE

Adolph, E. F. This Journal 125: 75, 1939.