Reports

Water Intake without the Act of Drinking

Abstract. A method is described that allows a rat to ingest fluid through a chronic gastric tube that bypasses the oropharyngeal cavity. In this situation long-term regulation of water intake occurs in normal rats and in the rat with diabetes insipidus. Under special circumstances, a remarkable degree of excess intake can be produced.

Many of the factors controlling food and water intake can be divided into two complex groups by the act of ingestion. Those operating immediately before ingestion, or the preingestion factors, include stimulation of the distance receptors and the chemoreceptors by food and water and sensory feedback from consummatory responses such as sucking, licking, chewing, and swallowing. Sensations from the upper gut, changes in the tonicity of the body fluids, and direct humoral influences upon the central nervous system constitute the second or postingestion group of factors.

Work done during the past two decades with esophagostomized animals has emphasized the important role played by preingestion factors in behavior involving oral ingestion. Bellows (*1*) and Adolph (*2*) demonstrated (i) that water-deprived dogs with chronic esophageal fistulae will refuse water for as long as 15 minutes after a draught taken by mouth but lost through the fistula and (ii) that the size of this sham-drunk draught is a remarkably accurate function of an accumulated water deficit. Janowitz and Grossman (*3*) have shown that the sham-feeding of hungry, esophagostomized dogs inhibits subsequent eating. And the essential outlines of the preference-aversion curve for salt, a complex form of salt-drinking behavior, can be seen in rats with esophageal fistulae (*4*). In addition, Teitelbaum's finding (*5*) that the hypothalamic-hyperphagic rat is overresponsive to the taste and texture of the diet suggests that preingestion factors play a crucial role in this striking disorder of eating behavior.

Long-term studies of voluntary intake in the absence of preingestion factors should contribute to the further understanding of their role in all these phenomena. With this in mind, a chronic gastric tube for rats was developed that is passed through the nasopharyngeal gastric tubes were first and oropharyngeal receptors. Adult, female albino rats carrying such nasopharyngeal gastric tubes were first trained to press a bar to obtain water for ingestion by mouth. A column of tap water 6 feet above the level of the animal's stomach was then lead to the gastric tube through flexible plastic tubing interrupted by a normally closed solenoid valve. The previously learned bar-press then opened the valve and allowed water to run by hydrostatic pressure directly into the animal's stomach. The animal could thereafter control the frequency with which a small amount of water was injected into its own stomach (*6*). The size of any single stomach load was controlled by the experimenter and was varied by changing the length of time that the valve was held open. This then became the animal's only source of water.

This water was delivered from the valve to the gastric tube through a length of polyvinyl chloride tubing. The thick-walled and extremely flexible polyvinyl chloride tubing maintained a patent lumen despite considerable lateral rotation and twisting produced by the movement of the animal during the night. Chewing of this tube was discouraged by light counterweighting over a small metal pulley suspended above the box and, for recalcitrant animals, by replacing the lower 4 to 5 inches with metal tubing. With the use of this tubing and automatic control and recording equipment, water intake under these unique conditions could be studied continuously, both day and night, for weeks at a time.

The gastric tube was made of a 2- and a 5-inch piece of stretched PE-90 polyethylene tubing joined by friction fit to the arms of a metal elbow made of a short length of No. 22 gauge hypodermic needle tubing bent to fit the shape of the snout. With the animal anesthetized with intraperitoneal injections of atropine (0.15 mg) and hexobarbital (13 to 15 mg/100 gm), the long arm of the gastric tube, stiffened by chilling in ice water, was carefully forced through the external naris and into the esophagus via the nasopharynx. The short arm of the tube was threaded under the skin of the snout and brought out through an incision between the animal's ears. The metal elbow was then embedded in the divided tissues of the superior border of the naris, thereby forcing the long arm of the gastric tube further down the esophagus and into the stomach. This final position was checked by indirect auscultation over the stomach during the injection of several cubic centimeters of air through the tube. The protruding short arm of the gastric tube, before being fixed to the skull with dental cement, was joined to a piece of No. 22 gauge needle tubing bent to project upward between the animal's ears. This thereafter served as the inlet to the stomach. The upper respiratory passages were kept clear by suction until the animal recovered from the anesthetic. Since this technique does not require abdominal surgery, abdominal infections were not encountered and the animals were usually eating and drinking normally the day after surgery.

Four normal rats and one rat suffering both moderate diabetes insipidus and hyperphagia, as a result of a single pair of hypothalamic lesions, were studied while they lived in open-topped wooden boxes (8 by 10 by 15 inches) with wire-mesh floors standing on urine collection pans. In order to familiarize them with the situation and with the necessity to press the bar to secure water, the animals were first trained to press the bar several times for each oral reward. When this behavior was well established, they were switched to direct intragastric self-injection. Purina chow pellets were available *ad libitum*, and the animals were weighed every day.

Figure 1 shows several typical days

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Type manuscripts double-spaced and submit one ribbon copy and one carbon copy.

Limit the report proper to the equivalent of 1200 words. This space includes that occupied by illustrative material as well as by the references and notes.

Limit illustrative material to *one* 2-column figure (that is, a figure whose width equals two columns of text) or to *one* 2-column table or to *two* 1-column illustrations, which may consist of two figures or two tables or one of each.

For further details see "Suggestions to Contributors" [*Science* **125**, 16 (1957)].

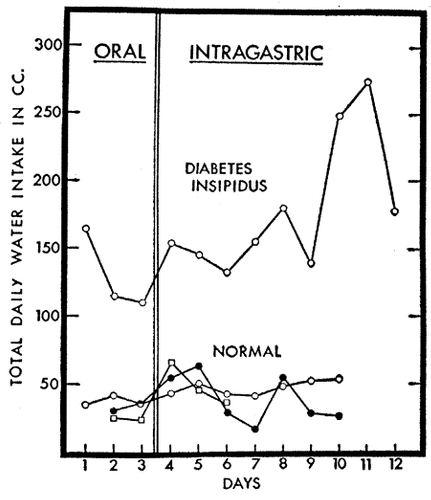

Fig. 1. Total daily intake of water obtained by three normal rats and a rat with diabetes insipidus during several typical days of bar pressing for oral intake and during a continuous period of bar pressing for direct intragastric injection.

of oral intake of water obtained by bar pressing and 3 to 9 nine days of direct intragastric water intake with each stomach load held within narrow limits for three normal rats and the diabetic rat. Note that total daily water intake remains within normal limits during the periods of direct intragastric self-injection. During these same periods the animals' weights remained essentially constant, and their average daily response totals were between 19.0 and 23.4 bar presses. In addition to demonstrating that the method described here can be used for long-term study of fluid intake, the relative constancy of these data show that preingestion factors are not necessary for the day-to-day regulation of water intake in the normal and the diabetic rat. This means not only that oropharyngeal sensations and feedback from consummatory responses are not essential here but also that this regulation can occur without the performance of the consummatory acts of licking and swallowing. Secondly, the data for the diabetic animal make it clear that the bar-pressing response used in the present method is sensitive to an increased need for water produced by a major alteration in the internal fluid balance.

The following additional facts support the view that bar pressing in this situation is related to the animal's need for water. First, the number of responses increases when the animal is required to press the bar several times for a single stomach load of constant size. A normal rat that had been pressing 20 to 25 times a day when every response was reinforced reached a peak of 74 responses when required to make five to six responses for a single stomach load. This adjustment required 2 or 3 days of experience with each of several successively higher ratios before normal regulation occurred. Second, the number of responses fell sharply in two well-trained animals (from 39 to 7, and from 46 to 9) when they were given *ad libitum* access to water by mouth with the bar in place but with the tube carrying water to the solenoid valve clamped shut. And in a third animal the solenoid valve was inadvertently disconnected overnight, depriving the animal of all water. In this case the number of responses rose from 55 during the previous day to 130 during the "deprivation" run. Thus the number of responses rises when water is more difficult or impossible to obtain and falls when it can be obtained freely by mouth.

The tendency toward excess intake that can be seen in Fig. 1 was dramatically revealed by progressively increasing the stomach load per injection between ranges of 0.75 and 42.0 ml for a normal rat and 0.9 and 63.3 ml for the diabetic rat over a period of several weeks. Despite a gradual fall in total daily responses, daily water intake rose rapidly from 30 ml/day to a plateau of 145 ml for the normal animal and from 200 ml/day to a plateau of 350 ml for the diabetic rat before falling off at the very high stomach loads. The normal as well as the diabetic animal produced large volumes of pale urine with the specific gravity of water during these periods of excessive intake. The loss of precise "metering" of water intake by feedback from licking and swallowing which has been suggested as an important role of preingestion factors may account for this phenomenon.

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References and Notes

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2. E. F. Adolph, *ibid.* **125**, 75 (1939).
3. H. D. Janowitz and M. I. Grossman, *ibid.* **159**, 143 (1949).
4. E. Stellar, R. Hyman, S. Samet, *J. Comp. and Physiol. Psychol.* **47**, 220 (1954).
5. P. Teitelbaum, *ibid.* **48**, 156 (1955).
6. N. E. Miller and M. L. Kessen [*ibid.* **45**, 550 (1952)], working with rats with chronic gastric fistulae, demonstrated that food injected into the stomach by the experimenter is a sufficient reinforcer for learning. This work suggested that the behavior required of the animal in the situation described here would be self-maintaining.
7. This work was done while I was a fellow of the National Foundation. I am grateful for the generous cooperation of Philip Teitelbaum in all phases of this research and to Eliot Stellar for his advice and criticism of the manuscript.

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Fatal Disease of Swine Due to Encephalomyocarditis Virus

Abstract. Encephalomyocarditis virus was isolated from the organs of swine dying during an outbreak of an acutely fatal disease occurring on a farm in Panama. The outstanding lesion was severe myocarditis. Pigs inoculated with the viral isolate developed a systemic infection with myocarditis.

During the past 20 years the encephalomyocarditis virus has been sporadically isolated from rodents and primates. It has been implicated as a cause of human disease. This report describes an outbreak of a fatal disease of swine due to the encephalomyocarditis virus. To our knowledge, the association of this virus with disease in domestic animals has not been previously recognized.

The outbreak occurred in July 1958 on a large commercial swine farm located 10 miles west of Panama City, Republic of Panama. Approximately 30 pigs died over a 20-day period in one overcrowded feed lot containing 300 3- to 5-month-old Duroc and Hampshire pigs. No deaths occurred in other pigs of the same age in an adjacent lot separated from the affected group by a narrow roadway.

The drove was frequently examined during the outbreak. The general appearance of the pigs was good. Some mild coughing and lameness were noted, which the owner did not consider unusual for his herd. All the pigs had been previously vaccinated for hog cholera. The feed ration consisted of corn with appropriate supplements.

Most deaths occurred at night; despite regular visits to the farm, the agonal stage was witnessed by only one of us, on a single occasion. The pig in question suddenly collapsed in severe dyspnea and died within a few minutes. The owner of the farm reported a similar observation.

Eight of the pigs that died during the outbreak were autopsied. Hydrothorax, hydropericardium, and ascites were frequently observed. The lungs were congested and edematous, with localized consolidation. The heart was soft and pale, with minute yellowish areas suggestive of necrosis. The meninges were slightly congested. Tissues for histopathological examination were selected from three animals which had died on the 6th, 10th, and 12th days, respectively, of the outbreak. The findings were severe myocarditis with round cell infiltration, vascular congestion, edema, and degeneration of the myocardial fibers; mild pneumonitis and pulmonary edema; mild meningitis and minimal congestion of the brain, with spotty areas of neuronal degeneration.