sex distribution. Each experimental group was treated in the following manner. The freshly collected animals were first kept for 5 days at room temperature (21° to 26°C) and supplied with a surplus of food and water. They were then placed in a constant temperature environment for 14 days. Each group of animals was acclimated to 35°, 25°, and 12°C, in that order. After 14 days at the constant temperature they were placed in separate runways within a photothermal gradient. After allowing 2 hours for the animals to become familiar with their surroundings, we recorded body temperatures at hourly intervals over an 8-hour period with a quick-recording Schultheis, 0° to 50°C thermometer inserted into the cloaca.

The photothermal gradient used was described by Stebbins and Eakin (*5*). The temperature range during the period of observation remained from about 25°C at the cool end to 55°C at the heated end. As pointed out previously (*5*), these temperatures were well above the upper and lower extremes of body temperatures recorded in these lizards during periods of activity in the wild. The animals were not fed while in the gradient, but water was supplied. The shelter provided by Stebbins and Eakin was removed.

In the fall (1958) experiments, animals were left in the runways for 24 hours at 20° to 25°C, then tested again when the gradient was established. We noted no difference in the group over the 24-hour "rest period." This indicated that the results probably were not attributable to a fatigue effect and that acclimation persists for at least this time interval. The spring (1959) groups were tested only once. After the desired body temperatures were secured, the animals were placed in cages and provided with food and water. They were kept at room temperature (21° to 26°C) for 7 days, then reintroduced into a constant temperature environment for acclimation to one of the other experimental temperatures.

Table 1. Influence of the previous thermal experience on mean preferred body temperature in *Sceloporus occidentalis*. Numbers after temperature are one standard error of the mean. C, control; E, experimental.

Groups	No. of animals	No. of readings	Combined means (°C)
	Previously acclimated to 12°C		
C	14	112	33.8 ± 0.10
E	43	344	33.7 ± 0.43
	Previously acclimated to 25°C		
E	25	220	33.2 ± 0.60
	Previously acclimated to 35°C		
C	21	163	33.6 ± 0.27
E	52	382	30.1 ± 0.65

In the spring a control group was treated exactly as the experimentals, except that during the 14-day acclimation period they were maintained at room temperature (21° to 26°C). Controls and experimental animals were placed within the gradient, and marked so that they could be returned to the same runway each time. Body temperatures of animals buried in the sand substrate were recorded along with those on the surface.

The results of the experiments are given in Table 1. The data show a valid statistical difference ($P = < 0.01$) between the mean preferred body temperature of animals acclimated to 35°C (30.6° ± 0.48°C) and the controls (33.8° ± 0.10°C). However, there is no significant difference between the 12° group and the controls. The 25° group, run only in the fall, did not differ statistically from the 12° group in preferred body temperature, but the mean of this group does fall between the 12° and 35°C groups.

Neither the 12° nor the 35° group differed between fall and spring; thus we could compare data from spring controls with all data on experimentals.

Since there were no sexual differences in preferred body temperatures within any of the groups, none of the data are separated on the basis of sex. Comparisons of the means for buried animals and those on the surface revealed no difference. Therefore, body temperatures of animals buried in the runways are included in both control and experimental groups.

Garside and Tait (*8*) did not attempt to interpret their findings other than to mention that the inverse relationship between acclimation temperature and preferred temperature was an unexpected phenomenon, since most studies with fish have shown a direct relationship between preferred temperature and acclimation temperature.

All work to date has shown the ability of lizards to thermoregulate, and some species show marked stenothermism during periods of activity. This suggests that there is a narrow thermal optimal range for the physiological processes of such species. However, when lizards are exposed to temperatures at or near the mean of this so-called optimal range for an extended period, a deleterious effect occurs. Wilhoft (*9*) found thyroid hypertrophy and decreased viability in *S. occidentalis* kept at 35°C. Dawson and Bartholomew (*7*) reported that *Sceloporus* that were acclimated at a temperature near the "optimal" (33°C) consumed oxygen at a lower rate than those acclimated to lower temperatures when tested at several temperature levels (16°, 28°, and 33°C).

Lizards exposed to constant high temperatures are forced into metabolic excesses; thus, the thyroid hypertrophy observed by Wilhoft (*9*) might represent a response to the increased oxidative processes, whereas the decrease in oxygen consumption demonstrated by Dawson and Bartholomew (*7*) might be considered a homeostatic response, probably one of many which function to prevent the animal from physiologically "burning itself out." Our results indicate a behavioral thermoregulatory response that probably accompanies, and perhaps is responsible for, the reduced rate of oxygen consumption. The desirability of a combined thermoregulatory and metabolism study is evident.

DANIEL C. WILHOFT
JAMES D. ANDERSON
Museum of Vertebrate Zoology, University of California, Berkeley

References and Notes

1. R. Cowles, *Science* **90**, 465 (1930).
2. H. Saint-Girons and M. C. Saint-Girons, *Vie et Milieu* **7**, 133–226 (1956).
3. S. Rodbard, *Federation Proc.* **6**, 191 (1947).
4. C. M. Bogert, *Evolution* **3**, 195 (1949).
5. R. C. Stebbins and R. M. Eakin, *Am. Museum Novitates* **1870**, 1–40 (1958).
6. C. H. Lowe and V. J. Vance, *Science* **122**, 73 (1955).
7. W. R. Dawson and G. A. Bartholomew, *Physiol. Zoöl.* **29**, 40 (1956).
8. E. T. Garside and T. S. Tait, *Can. J. Zool.* **36**, 563 (1958).
9. D. C. Wilhoft, *Copeia* **1958**, 265 (1958).
10. We express appreciation to R. C. Stebbins and O. P. Pearson for critical reading of the manuscript and helpful suggestions.

21 September 1959

Simple Telemetering System for Signaling High Rumen Pressures

Abstract. The construction of a modified Hartley oscillator transmitter activated through a pressure switch is described. When this device is placed within the rumen of a cow which is allowed unrestricted movement in the pasture, frequency-modulation signals are transmitted to a recording receiver whenever a preselected pressure is exceeded. The pressure at which transmission begins is determined by the capacitance across the coil of the circuit.

One of the difficulties encountered in studying bloat is the need for making intermittent or continuous visual observations of experimental animals. One or more individuals must watch the animals, and such observations are normally limited to daylight hours. Any method of recording intraruminal pressure which involves the use of tubes or wires connected to the animal limits its movement. Therefore it is desirable to have an instrument which will signal such pressures and yet allow unrestricted movement within the feed lot or pasture. Another disadvantage of visual observations or manual measurements is the lack of standardization between individuals and between research stations. Scores for bloat severity based upon these methods may range from 1 to 3 (slight, moderate, severe) on one scale or from 1 to 6 on another.

One instrument for measuring rumen pressures was developed by Kleiber (*1*). This instrument, called the "tympanometer," measures the amount of thrust necessary to force a stiff metal plate into a plane determined by a ring pressed into the flank of the animal. Although the inner tube of an automobile tire and a basketball bladder were used to calibrate this instrument, it does give objective results which can be measured in absolute values.

A capsule pressure-telemetering system for medical use for human beings has been developed for the Rockefeller Institute for Medical Research by the Radio Corporation of America (*2*). This capsule is approximately 20 mm long and 8 mm in diameter. The operating life per battery charge is about 3 days; the transmitting distance is only a few inches. These limitations make such a system unsuitable for studies of animals in pasture.

During work that was undertaken to develop a telemetering system for continuous recording of pressure changes within the rumen, a small, inexpensive, reliable transmitter was constructed. This instrument, which does away with the need for individual observations of the animals, signals to a radio receiver whenever rumen pressure rises above a preselected point. The materials and methods necessary for the construction of such a transmitter are as follows.

The circuit diagram shown in Fig. 1 illustrates a modified Hartley oscillator in which a 2N35 n-p-n transistor is used in place of vacuum tubes. The entire unit is approximately 25 mm in diameter and 150 mm long. Thus, it passes easily into the rumen by way of the mouth and esophagus but is large enough so that it will not pass from the rumen into the omasum or abomasum.

The parts required for construction are as follows: one 10-mh ferrite-core coil; one 390-kohm resistor; one 10-kohm resistor; one 2N35 n-p-n transistor; one Lucite case; one rubber cap; one micro pressure switch; one 9-volt battery; two 0.01-μf capacitors; one ceramic capacitor (100- to 400-$\mu\mu$f, as needed for tuning the circuit).

The life of a 9-volt battery in this system is approximately 12 days when there is continuous transmission. The

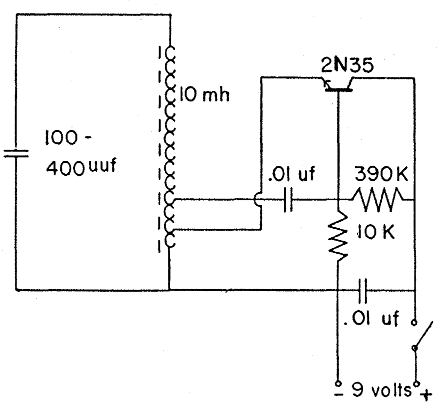

Fig. 1. Circuit diagram of the rumen pressure transmitter.

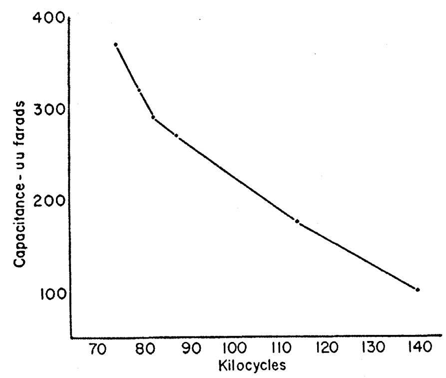

Fig. 2. Relationship of capacitance to frequency. A ceramic capacitor of 100- to 400-$\mu\mu$f capacitance, inserted across the coil, determines the frequency, in kilocycles, of a signal transmission.

life of the battery is greatly prolonged by use of a micro pressure switch. This switch is normally open, and there is no transmission or battery drain when rumen pressures are below a selected level. Whenever pressures exceed this level the system is activated, and it is when a high pressure is maintained for long periods that bloat occurs. If no bloat occurs, or if bloat is subacute, the life of the battery is indefinite.

The selection of the frequencies to be used depended upon several factors. The Federal Communications Commission permits low-power communication devices to be operated without a license provided they do not cause interference with the reception of licensed radio stations. This limitation, together with the low degree of interference and attenuation caused by the body wall, determined the selection of a transmitting frequency range of from 75 to 150 kilocycles. A relatively inexpensive all-wave radio is used as a receiver. The antenna for the receiver is a single-turn loop of rubber-covered wire (18-gauge), which surrounds the field. An antenna of this type tends to rule out interfering signals which originate outside the field, causes greater coupling between the transmitter and the receiver than antennas of other types and is less dependent upon the position of the animal within the field. The fence around the field has been used as an antenna, but stronger reception is obtained when the single-wire antenna is used.

The largest field in which this equipment has been used is approximately 150 yards square. Clear transmission is obtained within this area, with little outside interference. Inasmuch as this field is within a rather heavily populated and industrial area, the maximum area that can be covered with this equipment is not known at present.

The telemetering system can be used in two different ways, depending on the information desired. If one wishes to know only whether any of the animals are bloating, then all the transmitters are tuned to the same frequency and the receiver is set for this frequency. The pressure switch is adjusted for a given pressure (for example, 30 mm-Hg); below this pressure there is no transmission, but when this pressure is exceeded, transmission begins. Thus, the investigator need not observe the animals but will be informed whenever pressures exceed the selected level in any animal. If the investigator desires to know which specific animal may be bloating, each transmitter is tuned to a different frequency by inserting into the coil circuit a ceramic capacitor of a different capacitance; this will change the frequency of transmission. Figure 2 gives values for frequency versus capacitance. In this manner, ten animals may be telemetered on ten different frequencies, and by scanning this range with the receiver, bloat can be determined in individual animals.

The major disadvantage of this system is that the transmitter must be recovered by surgery or slaughter. However, the low cost of each unit and the long life of the battery should balance this disadvantage. By replacement of the battery, the unit may be used again and again (*3*).

LOYAL C. PAYNE

Department of Veterinary Science, College of Agriculture, University of Nebraska, Lincoln

References and Notes

1. M. Kleiber, *Rev. Sci. Instr.* **16**, 79 (1945).
2. J. T. Farrar and J. S. Bernstein, *Gastroenterology* **35**, 603 (1958).
3. This report is published with the approval of the director of the Nebraska Agricultural Experiment Station as paper No. 979, journal series. This work was supported in part by funds provided by Regional Project NC-27. I wish to acknowledge the cooperation and assistance in this study of Instrumentation Specialties Co., 1551 Ridgeway, Lincoln, Nebr.

14 October 1959