amount ingested was in the order of twice the amount excreted.

Although the wood rat appears to have several characteristics worthy of further investigation, the difficulties encountered in maintaining the animals under laboratory conditions make it unlikely that they will find widespread use. Not only was there a poor growth response to a purified type of diet, but reproduction under laboratory conditions was unsuccessful, as was also reported by Hall and coworkers (*5*) for the related Florida wood rat, *Neotoma floridana osagensis.*

References and Notes

1. Contribution No. 73 of the McCollum-Pratt Institute. These studies were supported by a grant from the National Institutes of Health, U.S. Public Health Service (HEW).
2. A. J. Carlson and F. Huelzel, *J. Nutrition* **36**, 27 (1948).
3. Acknowledgment is made to Curt Richter of The Johns Hopkins Hospital for his participation in this phase of the study.
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A Geothermal Measuring Circuit*

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Early in 1949 the U.S. Geological Survey undertook a program of geothermal measurements in drill holes in the Naval Petroleum Reserve in northern Alaska. A multiconductor cable for such measurements was specially designed in the Geological Survey for use in these arctic drill holes. The circuit may be of interest to others making precise temperature measurements at multiple points.

Thermistors were used as the thermal measuring elements because of their high sensitivity: a change in resistance, at room temperature, of −4.4 percent per degree Celsius change in temperature.

The circuit was designed to permit maximum accuracy with a minimum number of conductors in the cable. To achieve this, all the conductors were connected together at the bottom end of the cable (Fig. 1). This assures that each conductor in the cable has the same length and, what is especially important, that each has the same temperature and temperature distribution along its length. One of the conductors was then used as a common return lead for all the circuits. A thermistor was inserted at the desired position in each of the other conductors save one, which was reserved as a test lead. This allows an accurate determination of the circuit resistance for each thermistor circuit with only one conductor for each thermistor and without regard to the nature of the temperature distribution along the cable.

In operation, one terminal of a Wheatstone bridge is connected to the common lead (Fig. 1). The other terminal is connected, through a multipoint selector switch, to the desired thermistor lead. If R_θ is the resistance of the thermistor alone, R_L the thermistor circuit or lead resistance, and R_M the measured resistance value,

$$R_\theta = R_M - R_L. \qquad (1)$$

Because all the conductors in the cable are made of the same wire, all have the same temperature coefficients of resistance, α, β, ... Moreover, because of their adjacency and parallelism in the cable, all have the same temperatures and temperature distribution, when equilibrium with their surrounding medium has been attained. If the effective temperature of the cable is t (°C),

$$R_L = R_{L0}(1 + \alpha t + \beta t^2 + \ldots), \qquad (2)$$

where R_{L0} is the circuit resistance at 0°C. Since the test lead is one of the conductors, the resistance of the test circuit must also be

$$R_T = R_{T0}(1 + \alpha t + \beta t^2 + \ldots). \qquad (3)$$

Therefore,

$$R_L/R_T = R_{L0}/R_{T0}. \qquad (4)$$

Since this ratio is independent of temperature, it follows that

$$R_L/R_T = R_{LC}/R_{TC}, \qquad (5)$$

where R_{LC} and R_{TC} are the resistances of thermistor circuit and test circuit, respectively, as measured in the laboratory at some convenient calibration temperature t_C prior to the insertion of the thermistors in the cable. From this it follows that

$$R_L = (R_{LC}/R_{TC})R_T \qquad (6)$$

and

$$R_\theta = R_M - (R_{LC}/R_{TC})R_T. \qquad (7)$$

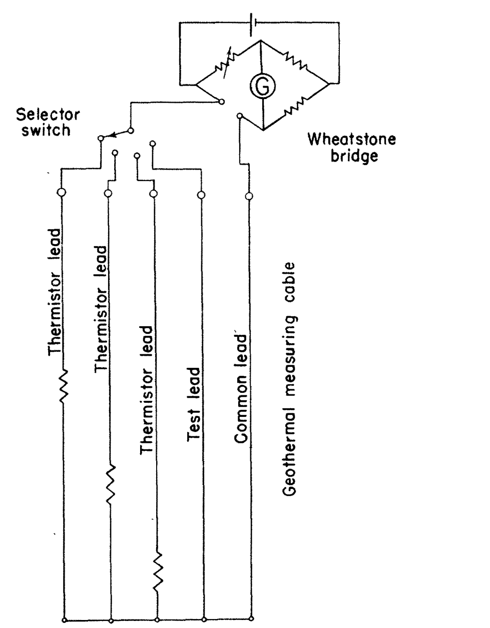

Fig. 1. Diagrammatic wiring circuit for geothermal measuring cable.

* Publication authorized by the director, U.S. Geological Survey.

The temperature t_θ of the thermistor may then be computed from the equation

$$t_\theta = [a/(b + \log R_\theta)] - c, \quad (8)$$

where a, b, and c are constants characteristic of the particular thermistor and are determined for each thermistor by prior calibration.

By using a four-decade Wheatstone bridge and a sensitive galvanometer with this circuit, it has been found possible to obtain a measurement precision in the field with a probable error of less than $\pm 0.01°C$.

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Comparison of Two Methods of Analysis of Rate of Leaf Initiation in *Zea mays* L.

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A method of growth analysis that, until recently, has been little emphasized is the determination of rate of leaf initiation. It has been used in this laboratory in the study of corn morphogenesis. The technique (*1*) involves the following steps: (i) in each sample, each corn seedling is dissected and the number of leaves produced to date is recorded; (ii) the data are seriated according to leaf stage; and (iii) the average number of days from the date of planting (or from date of pollination, if embryogeny is under consideration) to mid-point of (leaf) stage X is computed. We refer to this as the *mid-point* method. A curve representing data (marked X) from a current experiment on corn-seedling growth thus treated is shown by the solid line in Fig. 1. This method (*1*, *2*) has been used because it permits arithmetical calculation of the duration of each plastochron (leaf stage) by use of the formula,

$$t_X = \tfrac{1}{2}(x_2 - x_1) + \tfrac{1}{2}(x_3 - x_2),$$

in which X is the plastochron number, and x_1, x_2, and x_3 represent the time values from planting to mid-points of three successive stages.

A basic assumption in the utilization of this method is that the rate of leaf initiation is linear. Although this may be true in special cases, generally it is not true. Also, the method has some rather rigorous biostatistical requirements that may not always be attained in the average experiment. These requirements are that (i) the samples be taken at equal time intervals, (ii) the samples be of equal size, and (iii) at any initial or final sampling no more than one leaf stage be represented. Concerning the last point, when a sample comprises a range of two or more leaf stages, it may be assumed that only the tardy plants of the previous stage have been sampled at the time of initiation of the experiment, and only the more precocious plants of the latest stage have been sampled at the time of termination of the experiment. Thus, their time values contribute to longer and shorter calculated durations of the stage, respectively, than is actually the case.

An alternative method of calculation of rates of leaf initiation (*3*) has been used in a study of corn embryogeny. In this method, the average leaf stage per sampling date is determined; this is referred to as the *stage-per-day* method. It differs from the mid-point method by omitting seriation. The same data treated in this fashion are shown graphically as circles in Fig. 1. A comparison of the two curves shows agreement in general trends but differences in detail, because the second method is more sensitive to changes in rates. These differences are of considerable biological significance, but they are evident only if sampling intervals are sufficiently brief. Thus, the extremely long duration of plastochron 10 is obscured by the mid-point method because it distributes some extreme time values between plastochrons 9 and 11. Furthermore, the graph demonstrates the discrepancy between the two methods at the upper end of the curves. The mid-point method suggests an increase in the terminal rate of leaf initiation, whereas day-by-day analysis of the same data gives no indication of this. A similar discrepancy would have been noted at the beginning

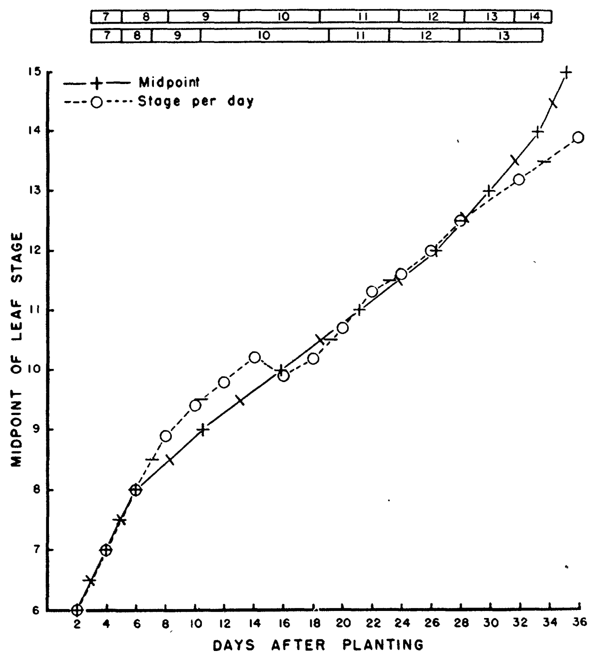

Fig. 1. Rate of leaf initiation of corn seedlings as determined by the stage-per-day method (broken line and circles) and the mid-point method (solid line and x's). Diagonal ticks on the solid line and the upper bar at the top of the figure indicate the duration of successive plastochrons as calculated by the mid-point method. Horizontal ticks on the broken line and the lower bar at the top of the figure represent the duration of successive plastochrons as determined graphically by the stage-per-day method.