compensatory process in the maintenance of species homeostasis, as is suggested by Doubleday (*5*).

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29 June 1956

Mobility of Calcium-45 after Injection into Western White Pine

Calcium is generally thought to be an immobile element in the plant (*1*), although a report of its redistribution in the peanut has been published (*2*). Williams, in a recent review of the literature on redistribution of minerals in plants (*3*), reported no instances of calcium mobility.

The use of calcium-45 in connection with other studies of mineral translocation in western white pine gave an unusual opportunity to study the mobility of this element (*4*). In 1951, 1952, 1953, and 1954, during July and August, trees of this species in various locations in northern Idaho were injected with solutions of calcium-45 in carrier solution. This was accomplished by attaching metal or tarpaper cups to the trees, sealing the junction between tree and cup, filling the cups with carrier solution, and then incising the tree with a wood chisel and hammer. At least 40 percent of the circumference was opened in this manner, with the chisel penetrating completely through the phloem and into the xylem about 1 to 1.5 in. The radioisotope solution was then pipetted into the carrier, mixed, and subsequently taken up by the tree with the carrier.

Trees of several sizes were used in the experiments. The Sands Creek, Three Mile Creek, and Clarkia Peak trees (Table 1) were all of pole size (50 to 70 years old and 65 to 90 ft tall), while the Hollywood trees were smaller, being 12 to 15 years old and 15 to 20 ft tall. The larger trees were injected with 1.25 to 3.78 mc of calcium-45 per tree, and the smaller trees received from 0.10 to 0.71 mc per tree. The carrier solution for the larger trees was introduced as a solution of 8 to 9 lit consisting of from 0.15 to 2 mole of Ca^{++}, 0.03 to 0.17 mole of K^{+}, 0.008 to 0.06 mole of NH_4^{+}, 0.32 to 2.5 mole of NO_3^{-}, and 0.002 to 0.02 mole of PO_4^{---}. The carrier solution for the smaller trees was introduced as approximately 0.5 lit of solution containing 0.04 to 0.4 mole of Ca^{++}, 0.03 to 0.04 mole of K^{+}, and 0.14 to 0.83 mole of NO_3^{-}. For both large and small trees, the solutions were made just acid to methyl red (*p*H 4 to 5) with HNO_3 and KOH.

Two weeks to a month after injection, the trees were climbed, and the foliage of the current year was sampled in various parts of the crown. The foliage samples were returned to the laboratory, dried at 70°C, and ground in a Wiley mill. A 2-g sample was then wet digested, the calcium was precipitated as the oxalate, and the precipitate was filtered off in small Buchner funnels and counted in a flow counter. Finally the precipitate was titrated to determine total calcium. The counts were corrected for coincidence, background, self absorption, half-life (to date of injection) and finally were expressed in counts per minute, per gram of dry tissue (70°C). These data are given in Table 1.

The year after injection, during the months of July, August, and September, most of the trees were climbed and sampled for the newly developed terminal and lateral buds. These buds were analyzed to determine whether they contained calcium-45; activity would indicate that the previously deposited calcium had moved into these tissues. These samples were analyzed as the foliage samples had been, and the results are given in Table 1. For a few trees it was possible to make a similar analysis of terminal and lateral buds developed and sampled 2 years after injection, and these are also listed in Table 1 for the trees for which data are available. For comparative purposes, it should be noted that the calcium activity in the buds is an appreciable percentage of the activity of the foliage accumulating calcium at the year of injection.

Data for one group of trees were calculated on a specific activity basis (counts per minute, per milligram of total calcium), and these are presented in Table 2. This calculation, which gives an estimate of the ratio of calcium-45 moving into the tissues compared with the total

Table 1. Calcium-45 activity in foliage and buds of western white pine at varying periods after injection.

Location of tree and year of injection	Counts/min g corrected to time of injection		
	Buds		Foliage
	1 yr. after injection	2 yr. after injection	In year of injection
1951, Sands Creek tree, No.			
1	41,400		86,000
2	27,300		92,000
3	46,300		48,000
1952, Sands Creek tree, No.			
4		17,400	3,900*
5		7,230	5,470*
6		2,410	5,180*
7		5,180	6,200*
1953, Hollwood tree, No.			
1	20,350	3,610	56,500
2	22,700	9,700	35,500
3	19,900	2,170	88,300
4	14,700	5,720	29,700
5	5,080	6,790	21,200
6	12,900	10,400	102,000
1954, Three-Mile Creek tree, No.			
1	16,100		59,000
2	36,100		13,710
3	2,680		4,920
1954, Clarkia Peak tree, No.			
1	6,600		13,240
2	4,410		4,800
3	15,730		31,400

* Foliage in year following injection.

Table 2. Specific activity (Ca^{45} counts per minute, per milligram of total Ca) in foliage and buds of western white pine at varying periods after injection.

Hollywood tree, No.	Counts/min mg total Ca corrected to time of injection		
	Buds		Foliage
	1 yr. after injection	2 yr. after injection	In year of injection
1	20,400	2210	8,940
2	22,700	5130	6,840
3	9,220	1270	16,900
4	12,200	3910	7,890
5	20,000	7900	5,300
6	11,300	7780	13,450

calcium there, makes the amount of calcium movement into the buds appear still more impressive. In most cases, on the specific activity basis, the 1-year-old buds have appreciably more calcium-45 in them than has the foliage on the tree shortly after injection.

These data, gathered from work during four different years and representing trees from four different areas, indicate that there was a substantial movement of previously deposited calcium into newly developed buds in this species.

The results indicate that calcium has considerably more mobility in western white pine than any previous reports would have led us to expect. We are conducting further investigations of this phenomenon.

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28 May 1956

Relationship of Hormone Dosage to Physiological Response

A traditional method for the presentation of the relationship between the response to a hormone and dosage is to plot the logarithm of the dose against response. Whereas this choice of coordinates is convenient when a wide range of dosage has been studied, it appears to lack theoretical foundation. It is the purpose of the present paper to suggest an alternative system of coordinates, which may find usefulness in certain situations.

This analysis is based on the fact that, whereas the physiological response to many endocrine products at low dosage levels is roughly proportional to dosage, an apparent saturation may often be achieved at high dosage levels, the response becoming asymptotic with respect to dosage. By analogy to the Michaelis-Menten concept that the abundance of enzyme-substrate complex limits the velocity of an enzyme-catalyzed reaction (*1*), it is suggested that the magnitude of a hormone-provoked response is limited by the abundance of hormone bound to appropriate sites on the target organ. Direct evidence for such binding is already at hand, in the case of insulin (*2*), as is the strong indication of approximate proportionality between the quantity of insulin bound by muscle and the physiological response, in this case, synthesis of extra glycogen (*3*).

Let Q equal the total number of sites for physiologically responsive attachment of hormone to a target organ, $[HT]$ equal the number of such sites occupied by hormone, and $[T]$ equal the number of sites not so occupied. Whence

$$Q = [HT] + [T] \qquad (1)$$

Assume the occurrence of a reversible reaction between circulating hormone H and target-organ acceptor sites,

$$HT \rightleftharpoons H + T$$

with an equilibrium constant given by the expression,

$$K = \frac{[H]\quad[T]}{[HT]} \qquad (2)$$

If the physiological response observed is now assumed to be proportional to $[HT]$, the abundance of target-organ sites occupied by hormone, then the maximal response will be observed when all available sites are so occupied:

$$Q = [HT] \qquad (3)$$

and half of maximal response will be observed when one-half of the sites are occupied and one-half are not so occupied, under which circumstances

$$[T] = [HT] = \tfrac{1}{2}Q \qquad (4)$$

If $[H]_{\frac{1}{2}}$ is defined as that concentration of circulating hormone necessary to provoke one-half of maximal response, then, from Eqs. 2 and 4,

$$K = [H]_{\frac{1}{2}} \qquad (5)$$

an expression which formally resembles that of Michaelis and Menten. From Eq. 2,

$$[T] = K\,\frac{[HT]}{[H]} \qquad (6)$$

and from Eq. 1,

$$[T] + [HT] = Q = K\,\frac{[HT]}{[H]} + [HT] \qquad (7)$$

whence

$$\frac{[H]}{[HT]}\,Q = K + [H] \qquad (8)$$

and

$$\frac{[H]}{[HT]} = \frac{K}{Q} + \frac{[H]}{Q} \qquad (9)$$

This transformation is analogous to that of Lineweaver and Burk (*4*), and the same expression (Eq. 9) may be reached from considerations resembling those of the Langmuir sorption isotherm (*5*).

If it may now be assumed that the concentration of unbound hormone $[H]$ is proportional to the dose administered, Eq. 9 may be employed as a basis for plotting of data. If dose/response is plotted against dose, a straight line should be secured with slope $1/Q$ and intercept (dose = 0) K/Q. In Fig. 1 is shown a sample of data selected from the literature showing fairly good linearity when the foregoing coordinates are employed. The data are those of Riddle and Bates relating dose of prolactin to increase in weight of the pigeon crop-sac (*6*).

The possible usefulness of this method of plotting is that, from measurement of slope and intercept, numbers may be obtained indicating the capacity of target organ to bind hormone Q and the affinity of hormone for such binding sites K^{-1}. Such numbers, of little meaning by themselves, may prove of interest in the study of responses to families of related hormones and of the altered responses to a hormone in the presence of antagonists, disease, and so on. A decrease in response to a hormone, may, on these coordinates, appear as an increase in the slope of the line, reflecting a decrease in Q, the total number of tissue sites available for binding. Alternatively, such a decrease in response may appear, when plotted, as a line of unchanged slope but with a higher intercept, indicating an altered affinity of hormone to tissue-binding site.

The linearity here observed can be anticipated only if the magnitude of the response is limited by the amount of bound hormone, all other necessary reagents for the response being present in excess. In some situations, such as the increased accrual of glycogen in rat diaphragm in response to insulin, this condition does not appear to have been fulfilled.

The results of the foregoing development have previously been briefly presented (*7*). During the preparation of

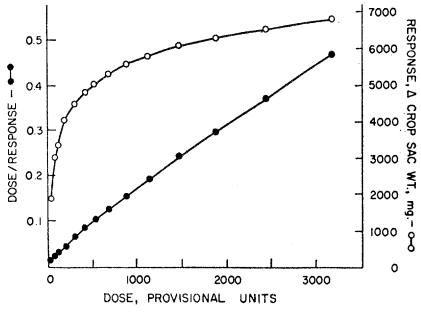

Fig. 1. Response, increase above control weight of crop-sac of a 450-g pigeon, plotted against dose of injected prolactin, in provisional units (open circles). The fraction, response/dose, plotted against dose (closed circles). Data are from Riddle and Bates (*6*).