XVIII. The medians of a triangle (mid-points correspond to the bisectors of the horns of the trihorn) are concurrent; but the altitudes are not concurrent.

XIX. The congruence group in the new metric is $X = mx + h$, $Y = m^2y + k$.

(4) In conclusion, I remark again that only horn angles of first order contact are allowed in the preceding discussion. If higher contacts are permitted, the theory becomes much more complicated (since each order requires a new theory of measure), and the complete conformal geometry of horn angles becomes *non-Archimedean*. The fact that angles of contact of different orders are not metrically comparable was first noted by Newton in the Principia.

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## UPWARD TRANSPORT OF MINERALS THROUGH THE PHLOEM OF STEMS

THE general opinion among botanists is that the mineral elements absorbed by the roots are transported upwards in the xylem with the water. Curtis[1] as a result of his numerous investigations has, however, suggested that at least some of the soil solutes ascend in the phloem. Mason and Phillis[2] dispose of the matter of solute conduction by the statement: "To sum up, ringing experiments have shown that soil solutes ascend the stem in the wood, but they have not demonstrated that they (soil solutes) may not also ascend in the phloem. It must be admitted, however, that the evidence available renders it very unlikely that they normally do so."

With a new tool available, namely, strongly radioactive elements, we have undertaken to clarify this issue. The installation of the new cyclotron equipment in the physics laboratories at the University of Michigan has made available fair quantities of strongly radioactive material. Phosphorus was chosen because it is an important element in every plant and because its half life is fifteen days, a period long enough to allow one to conduct several experiments with the same preparation. Red phosphorus was activated and then made into $KH_2PO_4$. This salt was made up into a 0.5 per cent. aqueous solution with a pH of 5 to 6. Rooted cuttings of geranium, *Sedum praealtum* and *Bryophyllum calycinum* have been used as plant material. These plants were chosen because the bark separates readily from the wood. The presence of the radioactive phosphorus in the plant was detected by means of an electroscope.

[1] O. F. Curtis, "The Translocation of Solutes in Plants." McGraw-Hill, 1935.

[2] T. G. Mason and E. Phillis, "The Migration of Solutes." *Bot. Rev.*, 3: 47–71, 1937.

As more details will later be published elsewhere, only a few experiments will be cited here. With *Bryophyllum* several experiments were performed in which part of the bark with several leaves was completely separated from the wood except at the base, and at this point the remainder of the plant was cut off. This left the plant with only a few leaves attached to the bark, which was connected with the roots through a portion of the unmutilated stem. In one of these experiments the piece of bark was 22 cm long and had four leaves attached to it.

The roots of this plant were kept in the active phosphorus solution for about 40 hours. At the end of this period the leaves were still quite turgid. The bark was cut up into pieces 2 cm long and the activity determined. Table I gives the results for this experiment. The electroscope discharged itself in 40 minutes, so that any time less than 40 minutes denotes active phosphorus in the plant material.

TABLE I

TIME REQUIRED TO DISCHARGE THE ELECTROSCOPE WITH 2 CM-LONG PIECES OF BRYOPHYLLUM BARK

| Distance above solution, cm | Time in minutes |
|---|---|
| 3 | 13.0 |
| 7 | 16.0 |
| 11 | 19.25 |
| 15 | 22.5 |
| 17 | 25.0 |
| 19 | 30.0 |
| 23 | 38.0 |

This shows that even in the last section, which was 23 cm above the solution, there was some radioactive phosphorus present. In this experiment the leaves were not tested, but in others where tests were made, active phosphorus was found to be present in them also.

In another group of experiments with *Bryophyllum* a complete section of the xylem, about 2 cm long, was removed from the stem, leaving the leaves connected with the roots only through the bark, which was left complete. In one of these experiments a well-rooted plant remained in an active phosphorus solution for 17 hours. Table II gives the results.

TABLE II

TIME REQUIRED TO DISCHARGE THE ELECTROSCOPE WITH 2 CM-LONG PIECES OF BRYOPHYLLUM STEM (SECTION OF WOOD REMOVED)

| Distance above solution, cm | Bark | Xylem underneath bark |
|---|---|---|
| 6 ..... | 8.0 min. | 20.0 min. |
| 8 ..... | 14.0 " | Wood removed |
| 10 ..... | 25.0 " | 35.0 min. |
| 13 ..... | 32.8 " | 39.5 " |

There is evidence here that phosphorus was conducted through the phloem of the *Bryophyllum* stem

and that some of this diffused into the xylem above the cut. A considerable quantity of the active element must be present before detection is possible by the electroscope.

To determine what may be the amount of active phosphorus in a plant with intact xylem as compared with one that has the xylem removed, experiments were performed with *Sedum praealtum*. The wood was removed from one plant, as in the *Bryophyllum*, and another similar plant with xylem intact was selected as control. The two plants were placed in the same solution and in one experiment kept there for 40 hours. They were both cut up at the same time, sections taken at the same levels and the quantity of active phosphorus determined alternately. Table III gives the results.

TABLE III

TIME REQUIRED TO DISCHARGE THE ELECTROSCOPE BY 2 CM-LONG PIECES OF SEDUM PRAEALTUM STEM

| Distance above solution, cm | Phloem | | Wood and pith | |
|---|---|---|---|---|
| | exp. plant | control | exp. plant | control |
| 3 .... | 19.0 min. | 15.5 min. | 26.0 min. | 19.0 min. |
| 7 .... | 21.0 " | 17.25 " | wood removed | |
| 11 .... | 26.75 " | 20.25 " | 32.0 min. | 24.25 " |
| 15 .... | 30.0 " | 26.5 " | 35.5 " | 29.0 " |
| 19 .... | 38.0 " | 32.5 " | 39.0 " | 37.75 " |

The difference in quantity of active phosphorus, level for level, between the two plants is remarkably small.

Experiments with well-rooted geranium cuttings have also been performed. The results are essentially the same as for *Sedum*.

These experiments show beyond a doubt that the radioactive phosphorus, in form of phosphate, is transported up the stem of a plant through the phloem.

The writers take this opportunity to express their thanks to Professor J. M. Cork, of the Physics Department, for his kindness in supplying them with the radioactive material, and also to Miss Alice Huse for her help with some of the preliminary experiments.

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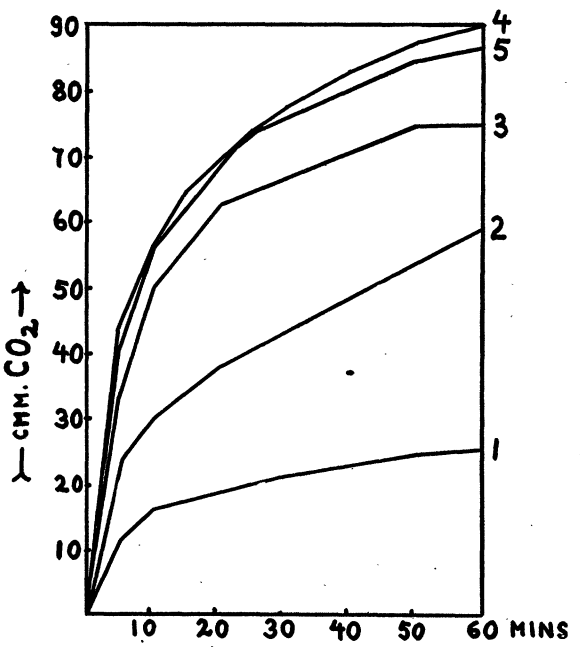
## SYNTHESIS OF CO-CARBOXYLASE FROM VITAMIN $B_1$

IF synthetic, crystalline vitamin $B_1$ is treated in the cold with phosphorus oxychloride in a molecular ratio of at least 1:2, a compound is formed exhibiting the properties of co-carboxylase.

The activity of the synthetic co-enzyme of carboxylase is tested in a system containing bottom yeast freed from natural co-carboxylase by extensive washing, pyruvic acid as the substrate, and magnesium as activator. The carbon dioxide formed by decarboxylation of the substrate, as determined in Warburg manometers, serves as the measure of activity. Up to the present the yield of synthetic co-carboxylase, as judged from the comparison with boiled yeast juice, has not exceeded 1.5 per cent. of the theory. The same results have been obtained using crystalline, synthetic vitamin $B_1$ preparations from two different sources,[1] one prepared by the synthesis of Williams and Cline[2] and the other by that of Andersag and Westphal.[3] A typical experiment is shown in the figure.




The main room of the Warburg vessels (total volume about 17 cc) contained 1 cc of washed dry yeast (*cf.* Lohmann and Schuster[4]), corresponding to 100 mg dry weight, varying amounts of synthetic co-carboxylase or boiled yeast juice, and 0.1 M. phosphate buffer, pH 6.2, to make a volume of 3 cc. After attainment of equilibrium there were added from the side bulbs of the vessels 0.3 cc of sodium pyruvinate solution, pH 6.2, equivalent to 5 mg pyruvic acid, containing 0.1 mg magnesium as $MgCl_2$. In addition to the foregoing, vessel No. 2 contained 0.2 cc of boiled yeast juice, corresponding to 20 mg of bottom yeast, vessel No. 3 contained 0.3 cc, vessels No. 4 0.9 cc, and vessel No. 5 1.8 cc of the synthetic co-carboxylase preparation No. II (1 cc equivalent to 2.2 mg vitamin $B_1$ hydrochloride). Vessel No. 1, containing only yeast suspension and buffer in the main room, served as the control. Atmosphere: Air; temperature 28°.

[1] The authors are indebted to Merck and Company and to the Winthrop Chemical Company for the supply of synthetic vitamin $B_1$.

[2] R. R. Williams and J. K. Cline, *Jour. Am. Chem. Soc.*, 58: 1504, 1936.

[3] Andersag and Westphal, cited by R. Grewe, *Zeits. physiol. Chem.*, 242: 89, 1936.