Educational, Scientific and Cultural Organisation were explained by Sir Alfred Zimmern and Dr. Julian Huxley, and this new Organisation was welcomed by the Council.

It was agreed, on the formal invitation of the Czechoslovak Government, to hold the full Third Session of the Congress at Prague in August 1947.

After the Oxford meeting, the delegates were received in London by the Royal Anthropological Institute, on the occasion of the Huxley Memorial Lecture by the Abbé Breuil on "The Discovery of the Antiquity of Man".

JOHN L. MYRES

TRANSLOCATION OF COPPER IONS IN PLANTS

By DR. E. M. DELF

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IN *Nature* of December 26, 1936 (p. 1099)¹, a method is described by A. C. Léeman for destroying *Dichapetalum*, a noxious weed of the Transvaal, by plastering a mixture of copper sulphate, calcium chloride and ordinary soil upon a short length of underground stem from which the 'bark' had been removed. Within twenty-four hours, leaves 15 ft. from the main stem were practically dead or dying, the downward movement being much slower (the ratios of the rates calculated from Léeman's figures being about 30:1). The movement of the copper ions was followed by placing freshly cut sections in a solution of potassium ferrocyanide, when a more or less deep red-brown colour could be seen where the copper arrived or accumulated. It was found that the movement took place "essentially" in the phloem, and it was suggested that the method could be used for the study of the translocation of solutes as such, the advantage being that the copper enters the intact sieve-tubes laterally by diffusion.

Although realizing that the interpretation of these results is by no means straightforward, the possibilities of the technique seemed worth exploring, and experiments have been made from time to time, as opportunity offered. Some of these appear worth recording in the light of recent work on translocation and on the movements of water in the intact plant. Thus towards the end of May 1937, the mixture was applied to a ring cut near the base of a low-growing shoot of horse-chestnut some 3 ft. in length. Next day the leaves were all dead, and successive sections revealed that the copper had ascended in the phloem almost to the apex of the shoot. The following October, one of the main roots of a large gorse bush was ringed 4-5 in. below the soil surface and the mixture applied to the wound, held in place with a band of adhesive plaster. Here the reaction was slow, a large branch immediately above the ring dying after 7-8 days, while the rest of the bush survived another 4-5 weeks, thus suggesting a connexion with the less active transpiration current of a sclerophyllous evergreen at the approach of winter. More recently (August 1945), the mixture was applied to the ring-barked base of a young willow (about 20 ft. high and some 6 in. in diameter). The only result observed was a slight darkening of the foliage next day. The tree was apparently unharmed, but was cut down later for other reasons, and there was no opportunity for further observations.

In 1942 an attempt was made to follow the path of the copper ions in actively growing woody shoots

(*Syringa vulgaris*, *Philadelphus* sp.) 2-3 ft. long, ring-barked and banded at corresponding positions a few inches from the base. Wilting of one or more leaves above the wound followed in 1-3 hours. At the first sign, the shoots were cut and examined, fresh, by means of successive (spaced) sections. In both kinds of shoots, the copper was evident in the phloem (mainly sieve-tubes) and also in the living cells of the xylem (parenchyma, medullary rays). (This recalls the results of Gustafsen and Darken², who found that phosphates (containing radioactive phosphorus) moved upwards in both xylem and phloem of rooted cuttings of willow, geranium and *Bryophyllum*.) In both *Philadelphus* and *Syringa* the movement was mainly in the upward direction, but the distances travelled were much greater in *Philadelphus* than in *Syringa*. The day was warm and sunny, and this may have been due to differential water deficit, or to some difference in the depth of the wound in the two plants.

In June 1945, the experiments were repeated more critically and also extended to other types. On this occasion the day was cloudy, after rain, with short sunny intervals, so no water-deficit would be expected; but in order to test this point, each experiment was set up with three similar shoots at about the same level on the plant. One was cut under eosine and examined at once for possible injection in the conducting tracts due to 'negative pressure'; the remaining two were ringed in corresponding positions. One was smeared with 'Vaseline' and wrapped in adhesive plaster, the other well covered with Léeman's mixture and similarly protected. Each pair was cut at the same time (usually after 2-3 hours), the control being cut under eosine while the experimental shoot was at once tested with potassium ferrocyanide. Several different plants were treated and tested on the same afternoon.

Typical results are given in Table 1. It will be noticed that in each case both xylem and phloem are involved, but in varying degrees. In two shoots of *Philadelphus* (1945) and in *Syringa* (1945) downward translocation also occurred involving both xylem and phloem, and in both the downward movement was much less than that in the upward direction (5-6 cm. *Philadelphus*, 4-5 cm. *Syringa*).

TABLE 1. TYPICAL EXPERIMENTS.

Plant	Duration of experiment	Distance travelled above ring		Remarks
		Xylem	Phloem	
<i>Syringa vulgaris</i>				
(1) 1942 ..	2-3 hours	3 cm.	1 cm.	
(2) 1945 ..	2½ "	15 "	21 "	
<i>Philadelphus</i> sp.				
(1) 1942 ..	2½ "	24 "	6 "	Lateral shoot ringed near base
(2) 1945 ..	2½ "	15 "	12 "	
(3) 1945 ..	2½ "	20 "	13 "	
<i>Viburnum opulus</i>				
1945 ..	2½ "	9-10 "	9 "	
<i>Solidago serotina</i>				
1945 ..	3½ "	5 "	17 "	Inflorescence axis ringed near base, just above soil.

In all these experiments there is an element of uncertainty as to possible injury to phloem by exposure, even though this tissue appeared to be intact after removal of the narrow zone of soft cortical tissue. Further observations were therefore made with balsams (*Impatiens glandulifera*), annual plants with sturdy growth having well-developed collenchyma beneath the epidermis, even in the younger parts. Ringing was effected without danger of injuring the vascular tissues beneath by merely stripping off the epidermis.

In the first instance, the stem of a 5-ft. plant was skinned on one side and banded about 3 in. above the base. Next day one or two leaves immediately above the band were drooping and soon died, but no further injury appeared. Investigation of this and other plants similarly treated showed that the collenchyma was very thick-walled in the basal region of the plant, and was only slowly and partially penetrated by the copper ions. The bands were therefore placed about half-way up the main stems, the epidermis being removed for about one-third of the circumference to the height of an inch, when the mixture was quickly applied and the whole enwrapped with layers of adhesive plaster. No subsequent sign of water shortage was seen with plants thus scraped and bandaged unless the Leeman's mixture had also been applied; the addition of 'Vaseline' was found to be quite unnecessary for the shorter time intervals used.

By this means it was found that the copper ions had flooded into all the living cells in the neighbourhood of the wound and had penetrated into phloem, xylem and the peripheral pith cells of the hollow stems. Traced vertically upwards, the red stain was after 2-3 cm. limited to the phloem, and a little higher, only to be found in the mature sieve-tubes. In all the treated plants (Table 2), *however short the interval before examination*, the stain was clearly demonstrable in the sieve-tubes all the way to the extreme tip of the stem, but downward penetration (where measured) was much more limited and the path was entirely confined to the sieve-tubes.

little use to compare rates of travel in the phloem in different plants; but the rapidity of the upward movement in *Impatiens* shows that maximal rates can only be obtained by using very short time intervals after banding (cf. Table 2, July 13). Thus the technique and timing of the operations are of the first importance. The experiments recorded for July 7 and 13 were performed after rehearsal and practice, but without any assistance; with suitable arrangements shorter time-intervals could be effectively explored. Circumstances interrupted the further prosecution of the work; but these rates (3-4 cm. per min.) are not maximal, since the times include an initial period of diffusion (or possibly of basic exchange) radially inwards which may be a slower process than the upward movement through the sieve-tubes. The rates found are about half that claimed by Léeman, but are much greater than those usually put forward (up to 1 cm. per minute) by workers in this field. It is not easy to see why the transport of mineral ions should be primarily upwards unless influenced directly or indirectly by the transpiration current. In this connexion it is noteworthy that M. P. Both³, using another species of *Impatiens*, found downward translocation of nitrogen facilitated by differences in humidity, and stopped by placing the receiving and supplying leaves in the same humid atmosphere.

In 1937 and again in 1940, attempts were made to use Léeman's mixture to detect the path of translocation in thalli of *Fucus* and *Ascophyllum*. Selected plants were marked on carefully sited rocks or

TABLE 2. *Impatiens glandulifera* (1945).

Date	Weather	Time of day	Time from banding	Distance travelled		Notes
				Upwards from top of band	Downwards from base of band	
June 19	Cool and cloudy	5 p.m.	20 hr. 46 hr.	26 in.	1½ in.	All leaves of one vertical series killed.
July 6	Bright sun; after rain (1) T. 23°-25° C. (2) T. 23°-25° C.	5.45 p.m.	45 min. 4 hr.	37 in.	Not examined	Laminae crisp—first sign injury.
		5 p.m.	30 min.	35 in.	4-5 in.	Laminae slightly flaccid.
July 7	Bright and warm	8.58 p.m.	5 min.	34 in.	Not examined	Banding 8.58-9.2 p.m. Removed 9.5 p.m. Cut into parts 2 min.
July 9	Hot sun	2.58 p.m.	2 min. 60 min.	23 in.	12 in.	One leaf drooping. All leaves at first slightly flaccid.
July 13	Sun after rain; breeze. (1) Plant in sun (2) Plant in shade and sheltered	5.50 p.m.	5 min.	27.7 in.	Not examined	Banding 2 min. Cut at 5.5 p.m.
		5.55 p.m.	5 min.	33.75 in.	Not examined	Cut into pieces 2 min. Ibid.

The results of these and other experiments suggest that the path and rate of travel of the copper ions are influenced by the specific nature of the plant and the degree of differentiation of the tissues, apart from possible differences in the permeability and sensitivity to copper ions. Apparently the water relations of the plant are also important. A water deficit (though probably slight) appears to favour downward in addition to upward movement in *Impatiens*; but the rapid ascent of the ions (July 7 and 13) appeared independently of this. *Impatiens* contrasted strongly with the woody types (Table 1) in that there was no sign of transport in the xylem except near the wound, but this contrast may not prove to be maintained in all circumstances. It is notable that in all these experiments with *Impatiens* there was little diffusion peripherally in the region of the wound, for in banded plants left to their fate, one vertical series of leaves would hang lifeless, while those of the other two orthostichies remained normal for many days after the operation.

Until more is known of such variations, it seems of

boulders as the tide receded. In the earlier experiments (at Filey) V-shaped slits were cut near the base of the stoutest stipes available, packed with the mixture (reinforced with a little added soil to give more cohesion) and bound with a rubberized tape. The plants were sought again after twenty-four hours; but some had broken at the wound, while in others the tape had loosened and the salts were washed away.

In August 1940 (at Criccieth), similar experiments were set up, using large plants of *Fucus serratus* (about 2 ft. long, 12-13 dichotomies seriatim, and 300-400 apices, the majority fertile), and also younger plants of *F. vesiculosus*. In these more sheltered waters, with more luxurious vegetation, all the plants survived operation, and by enclosing the bandaged region in an outer coat of stout adhesive sheet rubber, the entrance of sea water was effectively prevented. Three plants of *F. serratus* were treated with the mixture applied just above the second or third dichotomy (about 4 in. above the attaching disk): a fourth plant was treated with sand moistened with

sea water as a control. Two other similar plants were banded about half-way up the thallus, beneath a number of fertile segments.

All the plants were collected twenty-four hours after treatment. The experimental plants were all more or less tinged with a reddish-brown colour for two or three inches above the wound (presumably owing to post-mortem changes due to the poisonous effect of the copper), the rest of the thallus being a clear brownish-green.

Similar experiments were set up with *F. vesiculosus* var. *divaricata*. These each had only six series of dichotomies and about thirty apices of a clear olive-green colour, thus presumably in active growth. In this variety large bladders occur at all dichotomies (excepting those at the lowest levels) as well as in opposite pairs on the wings. In the experiments, the highest well-formed angle-bladders were slit open at the top, filled with the mixture or moist sand and the whole enclosed, while allowing freedom to the young branches on either side.

On collection twenty-four hours later, the branches beyond the bladders were noticeably discoloured excepting at the extreme tips and in small patches at the edges, the others on the same plants, as on the control, remaining olive-green. Below the wound, only an occasional small patch of discoloration was seen.

The plants were all wrapped separately and packed loosely in a tin. In this condition they remained alive for 2-3 days, but their colour was noticeably darkened, with less contrast between the normal and poisoned areas. They were afterwards dried under light pressure.

Cross and longitudinal sections of the dried material were cut (without wetting the razor), placed in a freshly made solution of 10 per cent potassium ferrocyanide for 20-30 min. and examined in dilute glycerine. With this procedure, a marked brick-red colour was seen in the primary medullary filaments of the stipe (or midrib) and also in those secondary filaments surrounding the medulla which had a relatively wide lumen and dense contents. The thick-walled, narrow, secondary filaments had everywhere apparently escaped the poison. The copper was followed upwards nearly to the apex of the thallus of *F. vesiculosus* (that is, 3-4 cm.) and appeared to have travelled for about 6-7 cm. upwards in the basal region of the stipe of *F. serratus*. In the downward direction, on the other hand, there was little sign of transport, and this only for about 2 cm. (*F. serratus*) or less than half a centimetre (*F. vesiculosus*).

Further study of the dried material was deferred until the experiments could be repeated under conditions more favourable for prompt examination, but these results, fragmentary as they are, definitely point to an upward translocation of copper ions (and presumably also of other mineral ions) along the broader medullary filaments. Downward translocation of phosphates and other substances was inferred by Wille⁴ from analyses of old and new regions of the thallus of certain *Laminariae*, but experimental demonstration of the path of transport has not been previously given, so far as I am aware, for any of the brown algae. The method should be capable of further development.

THEORY OF METALS

By PROF. P. GOMBÁS

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IN several previous papers¹ I have developed a statistical model of the metals which gives an account of the metallic bond of the alkali and the alkaline earth metals, and permits the computation of the fundamental constants of these metals without the aid of empirical or semi-empirical parameters. According to this model, the metal is composed of the lattice of the positive metal ions and of a uniformly distributed electron-gas consisting of the negative metal electrons (valency electrons). The lattice energy—from which all further conclusions can be derived in a simple way—is assumed to consist of the energy of the metal electron-gas and the interaction energy between the metal electron-gas and the metal ions. The energy of the metal electron-gas is composed of the electrostatic interaction energy, the exchange energy, the correlation energy and the zero-point kinetic energy of the metal electrons according to Fermi. The interaction energy of the metal electron-gas with the metal ions can be divided into three parts: first, the electrostatic interaction energy; secondly, the increase of the kinetic energy as a consequence of the penetration of the metal electron-gas into the electron clouds of the ions; and thirdly, the energy resulting from the exchange interaction between the metal electrons and the core electrons.

This model of the metals can be brought into a more appropriate form for further development and applications if we calculate the interaction energy of the metal electrons with ions—instead of on the basis of the commonly used electrostatic potential V of the ion—on the basis of a modified potential according to a formula I have derived²:

$$\Phi = V - \frac{1}{2}(3\pi^2)^{2/3} \varepsilon a_H v^{1/3},$$

where ε denotes the positive elementary charge, a_H the smallest Bohr radius of the hydrogen atom and v the electron density of the ions. Using this modified potential, we have to compute the absolutely lowest energy state of the metal electrons in the field of this potential without taking into account the exclusion principle for the metal electrons with regard to the electron states occupied by paired core electrons. This means that we have to neglect the above-mentioned second interaction energy term, the increase of the kinetic electron energy, which leads to an essential simplification. The energy resulting from the exchange interaction of the metal electrons with the core electrons can be computed in exactly the same way as in the case of free atoms³.

Hence we may express the lattice energy, taking all energy constituents into consideration, in the following way:

$$U = A_0 + \frac{A_1}{R} + \frac{A_2}{R^2} + \frac{A_3}{R^3} + \frac{A_4}{R^4},$$

where R denotes the radius of the elementary sphere containing one metal ion, and the coefficients, $A_i \dots$, are constants independent of R ; their value is determined only by the distribution of the potential and the distribution of the electrons within the ions and by the number of the metal electrons (valency electrons) per atom. All these quantities can be easily calculated. The constant term A_0 is

¹ Léeman, A. C., *Nature*, 138, 1099 (1936).

² Gustafsen and Darken, *Amer. J. Bot.*, 24, 615 (1937).

³ Both, M. P., *K. Akad. Amst.*, 38 (1935).

⁴ Wille, N., "Schwendener's Bot. Untersuch.", 321 (1899).