Regional Spread of Moisture in the Wood of Trees.

I.—Deciduous-Leaved Trees during the Period late Autumn to early Spring.

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With Plates CL–CLIX.

RESULTS obtained from the determination of the moisture content of samples of more or less seasoned wood for the Air Board suggested problems the solution of which could be looked for only from an examination of fresh unseasoned wood. Material which might serve to clear up some of the difficulties was very fortunately to hand, for, on mentioning the matter to Professor Balfour, I was informed that preparations had been made for felling two trees—an *Acer* and a *Platanus*—in the Royal Botanic Garden that day. Both trees were placed entirely at my disposal, and, as will be mentioned later, the results obtained served to emphasise our lack of knowledge on the question of the spread of moisture in deciduous trees. Examination of some other species at this time confirmed the main results obtained from these two trees.

Two possible lines of investigation suggested themselves: the examination of as large a number of deciduous trees as possible in the so-called dormant or inactive condition, or concentration on one particular species and the determination of the moisture spread at intervals throughout its leafless period. The former seemed to offer a fruitful field for study, but the latter was selected in spite of the fact that the terms dormancy or inactivity, as applied to the leafless condition of trees, suggest stagnation and would predicate no change in the moisture distribution from the time of leaf-fall until the buds open, or at least until they begin to swell.

The species selected for examination was *Acer Pseudoplatanus*. All the trees examined were grown under similar conditions in the Royal Botanic Garden, and all were about forty years old. Doubts might be raised of the expediency of basing any generali-

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sation on results obtained from a set of trees grown under similar conditions, *i.e.* subject to the same external factors. But the main conclusions of my investigation are such as appear to be independent of the influence of external factors except to the extent that the stage reached in the moisture spread at any particular time will, in an early district, be correspondingly in advance of that at the same time in a late district, *i.e.* the main conclusions apply generally to the species. From such observations as I have been able to make on other species of trees, I infer that my conclusions based upon *Acer Pseudoplatanus* may, with but slight modifications, be regarded as applicable to most if not all broad-leaved deciduous trees here.

Method of Procedure.—When the first tree was felled in October I was faced with the problem of how to utilise it to the best advantage so that

(1) the results would give some satisfactory idea as to the distribution of moisture throughout the trunk, and
(2) the work done on this tree might serve as a guide to the method to be followed in any similar work in the future.

With these objects in view, I finally decided to use three transverse cuts from the bole (from near ground level, from near the top of the bole, and from a point nearly midway between these two) and also two transverse cuts from the crown (one from near the bottom and one from about the middle of the leader). These five cuts were all about 4 cm. thick, and were all sawn off just after the tree was felled. Of each cut I used a strip of 3–5 cm. breadth from the outside to the centre. Each of these strips was then chipped up into smaller blocks, the moisture percentage of each of which was determined separately.

As already mentioned, the work done on this tree was to be regarded, to some extent at least, as experimental. How far this is the case may be understood by stating that whereas in this tree the moisture percentage of only some 66 pieces was ascertained, in the remaining trees the numbers were 278, 386, 394, and 407.

Generally in these trees six transverse cuts were selected, three from the bole, as in the October tree, and three from the crown, the third one here being taken from higher up on the leader. The larger number of pieces examined from the later trees is accounted for by two facts :

(1) the individual pieces were much smaller, and
(2) instead of using one strip from the outside to the centre, I used four strips from each transverse cut.

The small blocks were put in a drying oven which was kept at 100–105° C., and weighed at intervals of twenty-four hours until the loss per cent. in a twenty-four hours' period was less than 0·5 per cent. The moisture content of the original block was taken as the loss of weight in drying, and this moisture content, expressed in terms of the dry weight, was calculated separately for each block.

Graphic Representation of Results (Plates CLV–CLIX).—After calculating the moisture content of a number of specimens, I decided that probably the best method of illustrating the results throughout each tree was by graphs rather than by the tabulation of series of figures. The number of rings in each of the transverse cuts is plotted horizontally (2 mm. = 1 annual ring), and the moisture percentage vertically (1 mm. = 4 per cent.). In each case the line representing the middle line of the transverse cuts is taken as a base line representing a moisture content of 80 per cent., and these base lines are spaced out proportionately to the distances of the transverse cuts above ground level. The points plotted are the middle points of the small blocks as determined by the number of annual rings in each. No attempt whatever has been made to give the resulting polygons the appearance of graphs, as I thought it advisable in this preliminary investigation merely to join up the actual points plotted.

In examining these graphs it should be noted that whereas the general trend of the graphs is comparable, any particular series of similar points may not be strictly comparable, *e.g.* the first observations in the cuts of the October tree (see Plate CLV) from below upwards represent the moisture percentage of the outer one, four, six, two, and seven years' wood respectively.

In the case of the October tree (see Plate CLV), the left-hand side represents the younger wood and the right-hand side the centre of the tree. In the remaining trees (see Plates CLVI–CLIX) the oldest wood is in the centre of the graphs and the youngest wood at the right- and left-hand sides, *i.e.* in the October tree the graphs represent the moisture distribution from the outside to the centre, whereas in the remaining trees they represent the distribution from the outside to the centre in two directions.

Coloured Illustrations (Plates CL–CLIV).—In addition to the graphs which, as stated, give the moisture distribution throughout the trunk of the tree, an attempt has been made to show diagrammatically the stages through which each part of the trunk passes in the leafless period. The circles represent the transverse section of the trunk, and the colour distribution corresponds to the moisture distribution. It must be noted here that whereas these diagrams represent the average state of the bole of the trees examined, the whole length of the bole is not necessarily at the same stage at any particular time, and in fact very seldom are even the quadrants of any one section in exactly the same phase at one time.

Dates and Method of Felling Trees and of Cutting the Selected Transverse Sections.—The first tree was felled on the morning of 24th October 1917 when only a few half-withered leaves remained on the crown, *i.e.* at the time when foliar activity had just ceased for the year and at the commencement of what is usually regarded as the tree-felling season. Preparatory to felling the top of the crown was taken off, as were also the main branches, the latter being sawn off at about 1 m. from the trunk. Immediately after felling the trunk was taken to a sawmill close by where the cuts selected were sawn off.

The second tree was felled on 14th December 1917, in the afternoon. For convenience of felling some branches were cut off at about 1 m. from the trunk, but otherwise the tree was felled entire. Immediately after felling the bottom cut selected was sawn off. Next morning the remaining five selected cuts were sawn off, and the work of chipping up and weighing was completed on the following day.

On the morning of 5th January 1918 the third tree was felled. In this case only one branch was removed preparatory to felling. Felling took place in the middle of the severe snowstorm then being experienced and during hard frost. Just after felling only the bottom selected cut was sawn off. After work was finished on this cut an examination of the tree showed that it was bleeding rather freely from the cut branch and from another near it which had been damaged in felling. On account of the bleeding I had all the remaining cuts sawn off, and these were stored in a cool place during the remaining two days necessary for the chipping up and weighing. As bleeding from cut branches has been mentioned, I may state that this was the only tree of the series on which bleeding from small or main branches was observed.

The fourth selected tree was felled early on 4th February 1918. The tree was felled quite entire, there being in this case no necessity to remove branches preparatory to felling. All the selected cuts were sawn off immediately after felling, and no branches were removed from the crown until it was necessary to do so for sawing operations.

On 23rd March 1918 the fifth tree was felled quite entire in the morning. Immediately after felling all the selected cuts were sawn off, and the work of chipping up and weighing was proceeded with continuously till finished.

Several trees have been examined since the date of the one last referred to, and it is intended that the work should be continued throughout the summer. In the meantime, however, it has been decided to publish the main results derived from the examination of the five trees enumerated. This course of action has been decided on primarily from practical considerations. Under present conditions, when all questions affecting timber are of the utmost importance, it is desirable that any new facts bearing on the subject should be published as soon as possible, and, moreover, since the period under survey—October to March—includes the extreme limits of what used to be regarded as the felling season, the results supply us with some definite knowledge as to the varying moisture spread in *Acer Pseudoplatanus* throughout the felling season. From a more scientific point of view the course of action is based on the consideration that the five trees have been examined at various times throughout a distinct phase of the tree's life, viz. the dormant or, as it is often loosely and erroneously called, the inactive period. The first tree was examined at the time when foliar activity had just ceased for the year, and in the March tree the buds were almost on the point of bursting. Many problems of scientific interest have arisen in the course of the work, but discussion of these must be omitted for the present as far as possible. The main question to be dealt with in the present paper is: What is the moisture distribution in felled timber throughout the felling season? A true appreciation of these new facts and their practical bearing would appear to be desirable, if not essential, for the successful handling of timber.

With this object in view, I have decided to treat the trees seriatim, giving under each tree the main results derived from its examination, and afterwards to give a summary of the main conclusions for the whole period.

Results obtained from the October tree:—

1. That as regards the bole the *centre is decidedly the richest in moisture*, and that as regards the crown the region of maximum content is also in the central area, but some little distance from the actual centre.

2. That the moisture percentage of the *centre decreases upwards*.

3. That the outer few years' wood contains a comparatively large amount of moisture.

4. That the percentage of moisture in the *youngest wood increases upwards*.

5. That between the two regions of maximum content there is a region of lower moisture content, the moisture content, however, showing a more or less uniform increase towards the centre, and

6. That the *lowest section shows most markedly the pronounced accumulation of moisture in the centre.*

Although the graphs showed a transition in the matter of moisture content, more or less easily traceable from that of the lowest to that of the highest cut, it was not quite clear how the graphs should be correlated. Imbued with the prevalent idea that the dormant condition into which a tree passes on losing its leaves presupposes practically no movement of moisture during that period, I expected to find a more or less uniform distribution of moisture in the transverse sections at least of the bole. And again I could not account for the large accumulation of moisture in the centre. Was it a relic of the active season just ended, a condition which would prevail throughout dormancy, or was it the commencement of some new movement consequent on the stoppage of foliar activity? And another phase of the problem was: Were the results obtained characteristic of the species for the time of year or rather for this particular stage in the tree's cycle, or were they peculiar to the particular tree examined?

I had these points particularly in mind when the second tree was felled in December. From it the following main results were obtained:—

1. That the *central region is the richest* in moisture.

2. That the moisture percentage of the *centre increases upwards* until the first cut from the crown is passed, and that *above this there is a marked fall* in moisture in that region.

3. That the *younger wood is no longer a marked maximum area.*

4. That the percentage of moisture of the *extreme outside rings* tends, on the whole, to *increase upwards,* and that this percentage is lower than in October.

5. That there are indications in the lower cuts of a new disposition of the moisture, viz. that *the region of maximum moisture is moving away from the centre,* and

6. That *this movement is most pronounced in the lowest cut,* and becomes less marked upwards.

What, then, has happened between October and December? Comparison of the two sets of graphs for these months shows that the absolute moisture content is greater in December than in October. The additional moisture is probably due to root activity, the expression of which is shown in the younger wood in October, where, as already indicated, there lies one of the regions of maximum moisture. Reduced root activity is probably responsible for the lower percentages of moisture of the younger wood in December. Transpiration is then at its minimum and may, for the present, be regarded as negligible; I do not mean to infer that transpiration in winter is wholly negligible, but that for present purposes it is probably a negligible quantity. The roots being still active and transpiration being negligible, how is the additional water disposed of ? A glance at the graphs will, I think, readily answer this. It will be noticed that the graph of the fourth cut of the December tree is very similar to that of the lowest cut of the October tree, except that the percentages in the intermediate region are slightly higher. From this similarity, and from the gradations of moisture spread traceable between the first and fourth cut of the December tree, it is not unreasonable to presume that in the interval between October and December the graph of every part of the trunk up to and including the lower part of the crown would be at one time or another, though not simultaneously throughout the whole area, similar to that of the lowest cut of October or the fourth cut of December. In other words, water resulting from continued root activity is no longer required, to any great extent at least, in the crown, and is stored up in the centre of the tree until a condition represented by the lowest graph of the October tree, but with slightly higher percentages in the intermediate region, is attained. The reason for predicating this slightly higher percentage is that from comparison with other results I believe that the October tree was felled just before storage was completed in the lower part of the bole.

Before leaving the December tree we must note that both the storage of moisture in the centre of the trunk and the movement of the maximum moisture region away from the centre commence at the bottom of the trunk.

Just as was the storage of moisture in the centre of the trunk in October, so was this radial movement of the maximum moisture region of which we have just seen the commencement an unexpected happening. Was there any justification for comparing the two sets of graphs and drawing conclusions from them, or did the two sets of graphs differ no more than what might be expected from any two trees taken at random ?

To test the validity of the conclusions drawn from a comparison of results obtained from the October and December trees, the third tree was felled in the middle of January. This tree gave the following results :—

1. That the *central region* is still the *richest in moisture*.

2. That, with the exception of the bottom cut, the moisture percentage of the *centre increases upwards*, and that this increase continues up to the top cut selected.

3. That the moisture content of the outer few years' wood resembles that of December.

4. That, although the percentage of the extreme outsides is rather erratic, there would appear to be some relationship

between this percentage and the disposition of the moisture in the inner parts of any one transverse cut. Apart from this bare statement I reserve comment on the point.

5. That the *movement of the maximum moisture zone away from the centre,* of which we saw the commencement in the December tree, is now *very pronounced,* and

6. That, as before, this movement is *most pronounced at the bottom of the trunk.*

In addition to the results summarised above, it may be noted that the examination of the January tree removed any lingering doubts as to the main conclusions being of general application to the species.

Comparison of the graphs for December and January shows that in the interval the trunk as far up as the highest selected cut has completed its storage in the centre, and at the top is apparently—from the shape of the graph—already moving out of that condition.

Doubts as to whether the results were applicable to the species or only to the individual were now replaced by doubts as to whether external factors were influencing the moisture distribution. The resulting graphs showed such marked inequalities in the distribution of the moisture that there appeared some justification for the supposition that the extreme frost experienced about the time of the felling of this tree might have been acting as an arresting or retarding agent. In these circumstances it became necessary to examine another tree.

To summarise the results obtained from the February tree would be but to repeat what has been written for the January tree. One very important result was, however, obtained, namely :—

That a *powerful external agent,* represented by the extreme frost of January, *had apparently no effect* whatever on the moisture movement.

And again more marked than in the January tree is the diminishing moisture content of the outer few years' wood.

To what extent would the concentration of moisture towards the outside proceed ? And would it be possible to trace it before the new factor of root activity commenced ?—were questions which now suggested themselves. By this time I had formed the opinion that this stored moisture would probably not be called on until the buds had burst. In the February tree the buds had just perceptibly swollen, and, though not without some hesitation, I deemed it safe to leave the examination of the next tree until the buds were just on the point of bursting.

As already stated, the fifth tree was felled towards the end of March. On a cut branch placed in water several buds were open on the third day after felling.

Summary of results from the March tree :—

1. That the *central region* is practically throughout the *most deficient* in moisture.

2. That the moisture percentage of the *centre increases upwards.*

3. That the *outer two years' wood is comparatively dry,* and

4. That the *maximum moisture region is now most markedly on the outside,* just inside the two-year-old wood.

The facts which I have stated seem to justify the following statements :—

With the decrease or certainly with the cessation of foliar activity for the season the tree immediately commences its preparations for the next season. The first phase of its activities is the storing up in the centre of the trunk of a large supply of moisture. This storage commences at the bottom of the trunk. Until a full explanation of the process or processes is available, it will be more convenient to designate this the *storage condition.* By the time that the centre has received its quota of stored moisture far up the trunk, another movement has begun causing a rearrangement of the moisture at the base of the trunk. I do not say that the two movements are absolutely independent. One may be governed by the other, but for lack of understanding of the processes involved, I find it more convenient for the present to speak of them as distinct.

With this proviso, and as I interpret the phenomena, the processes may be in brief general terms stated thus :—

As the result of the water moving inwards from the outer zones, beginning at the base of the trunk there is created an area of maximum moisture content in a transverse plane at the centre of the trunk. This inward current and the consequent plane of maximum moisture content at the centre gradually extends upwards in the trunk to the topmost region, but before this is reached and the centre of the trunk at the top of the bole has become a storage region of maximum moisture content a radial movement has begun at the bottom of the trunk which likewise progresses upwards, and through it the region of maximum moisture content passes almost to the outside of the trunk, leaving the centre as the dryest region. The movements upwards and radial, both inwards and outwards, are going on synchronously at different levels in the trunk.

One point which may not be without its practical bearing is that the bole and crown parts of the trunk are in continuity so far as these processes are concerned. The reason for examining two transverse cuts from just below and just above the lowermost branches of the crown was that I had thought the branching might have some influence on the moisture disposition. In this I was evidently mistaken, so far at least as the winter condition is concerned, for the graphs show no sudden change at the junction of crown and bole.

A glance at what I have spoken of as the intermediate region in the storage condition shows that in the graph it is represented almost by a straight line rising gently towards the centre. For the purposes of plotting results the units for the annual ring and for the moisture percentage were finally fixed by trial, so that this region should be represented by almost a straight line. The reason for this was that in the storage condition it was observed that this intermediate region showed a steady increase in moisture percentage towards the centre wherever the annual zones of wood were at all uniform. Higher percentages resulted from close-grown timber and lower from faster grown. Hence for evenly grown timber I believe the graph of that part would be represented by a straight line. That narrow annual rings contain higher percentages of moisture finds its counterpart in the various methods for preserving timber by impregnation, where, I believe, it has been found that more of the preservative is absorbed by narrow- than by wide-ringed wood.

As already stated, this survey includes the extreme limits of what used to be regarded as the felling season. From the time that, to use the common expression, " the sap was down " to the time " the sap was up " was it not generally accepted that the moisture content was uniform or nearly so ? I have qualified this statement as to uniformity somewhat because increase in the total amount of moisture present in a deciduous tree in its leafless condition had already been proved.* Hartig states that the moisture-content of Birch increases from September when it is at its minimum, to March when its maximum is reached, and that in the case of Beech the month of maximum moisture-content is December. These results, it must be borne in mind, are applicable to Central Europe, and need not necessarily be absolutely true for this country. No statement was hazarded as to which part of the tree took up additional moisture or as to how this moisture once in the trunk was got rid of. The expression " the sap is down," I think I have proved meaningless as regards *Acer Pseudoplatanus* at least. There is an ascent of sap throughout the season, as

* R. Hartig, *Untersuch. a. d. forstbot. Inst. Münch.*, II.

shown by the leader some little distance behind the top of the crown not completing its storage until well on in the season. If expressions regarding the sap are to be used, they must be, in view of what I have shown, some such as " the sap is in " or " the sap is out."

During the felling season, then, trees with very varying moisture distribution are being cut down. At the beginning of the season the centre of the tree is very wet, at the end of the season there is a very wet region almost on the outside and the centre is very dry. Between these two extremes there are all the intermediate stages. Which is the best condition from the point of view of the seasoning of the timber ?

Are not the main reasons for winter felling of deciduous trees simply :

1. Custom.
2. Availability of labour.
3. Absence of leaves overhead and consequent light penetration.
4. Damage to undergrowth reduced to a minimum, and
5. The slower seasoning of the timber and risk of cracking reduced to its minimum ?

There is in this country a deeply rooted prejudice against summer felling. Asked his reasons against summer felling, a forester will usually give his individual interpretation of " the sap is then up." This expression has already been dealt with and no longer holds as an argument against summer felling. Though undoubtedly there is a greater supply of labour available in the winter, labour has no bearing on the present question and cannot be treated of here. Long-established custom can, I am afraid, be changed only by necessity. But in the present times even this deep-rooted custom has had to yield, at least in many cases. Kiln-seasoning has now been so far perfected that, according to some authorities at least, the quality of the timber is in no way reduced by the artificial method. Does the distribution of the moisture at the time of felling affect in any degree the successful artificial seasoning of the timber ? The first stages of the artificial method may be regarded as providing a safeguard against any defects which might otherwise arise from inequalities of moisture distribution in the untreated timber.

There is one other way of regarding the results of the present investigation with respect to the popular opinion on sap distribution. Trees at the commencement of the felling season are very wet in the centre, at the extreme end of that season the bulk of the moisture is on the outside, and during the season there are all the intermediate stages between the two.

Reasons against summer felling have been advanced based on the quality of the timber cut then. I have seen no proof that summer-felled timber is poorer in quality than winter-felled. It is possible that seasonal variations in the composition of the sap, apart altogether from the question of the amount of sap, may result in the walls of the various tissues being differently impregnated during seasoning. But such speculations lead us into the question of what seasoning really is, and what chemical reactions are involved—still a practically untouched field of study.

Having dealt with the expression " the sap is down," I feel that something must be said of its companion " the sap is up," even although in doing so I go beyond the trees dealt with in this paper. " The sap is up," or, as occasionally put, " the sap is in the bark," refers to the condition when the bark is easily separable from the wood, and this condition of easy separation is the result of the cambium swelling up preparatory to the year's growth. Results obtained from more recently examined trees show that for this condition it is unnecessary to predicate root activity. A more accurate expression would probably be " the sap is out in the bark."

To the practical man several queries may now suggest themselves: Are these new facts as to moisture movements to be regarded as of general application to *Acer Pseudoplatanus*, wherever grown? and further, Can anything be said as to other deciduous trees?

To the first query I can only reply that all the trees examined were grown under similar conditions, and that I have, therefore, no actual experimental evidence on the point. The impartial reader will, however, grant me, I think, that the results are not such as lend themselves to explanation by the bringing in of environmental factors. It has already been shown that one very potent external factor—severe frost—had apparently no effect whatever on the movement or movements of moisture. The actual moisture percentages and the stage reached at any particular time may be, and I have little doubt will be found to be, influenced by external factors, but I see no reason whatever for not accepting my general conclusions regarding the spread of moisture in this particular species.

Do all deciduous broad-leaved trees in temperate regions behave in a similar way throughout their leafless period? Although I believe that with slight modifications of detail the process will eventually be found to be of general application, it is yet too early to be quite positive on the point. It may be well to give such evidence as I possess which leads me to state this belief.

1. *Platanus acerifolia*, about forty years old, felled on the same day as the October *Acer*, gave the same general result as the *Acer*, viz. a decided accumulation of moisture in the central area, and what appeared to be the commencement of storage in this region in the two next higher cuts. The percentages were higher throughout the lowest cut, but the chief differences of detail were that there was a decline in the percentage right to the storage region, and this region was not the actual centre but some little distance out from the centre. Was the latter detail influenced by the fact that the tree had lost the top of its crown a year or two previously?

2. *Betula pubescens x verrucosa* (felled 2nd January 1918) and *Betula verrucosa* (felled 24th January 1918) have given, as far as the results have been worked out, very similar graphs to those of the December *Acer*.

3. *Crataegus Oxyacantha* (felled 5th March 1918). Here once more I find myself wandering beyond the limits set in this paper, since the buds were just open on this tree at the time it was felled. However, the results, as far as at present available, tend to confirm the wider application of these new facts since they are similar to those of the *Acer* in the same condition.

Of true heart-wood trees I have but scanty information.

1. A very old tree of *Ulmus montana* was felled in November, but unfortunately the centre was not sound. The results showed a sudden and very marked increase in moisture percentage immediately on entering the heart-wood.

2. *Quercus cerris*, thirty-four years old, felled 8th March 1918, gave results which, so far as available, correspond exactly with those of the similar cuts in the December *Acer*. From a solitary example, and that one with only some 6 cm. of heart-wood at the base of the trunk, it would be rash to draw conclusions, and yet the similarity of the curves suggests that in this case sap-wood and heart-wood are indistinguishable in their functions as regards storage and movement of moisture, *i.e.* the results gave no indications of two regions functioning differently.

From such evidence it would be unwise to draw inferences with regard to heart-wood trees. Arrangements have, however, been made to carry out as far as possible during this year the examination of a series of heart-wood trees on the same lines as that done for *Acer*. Whether heart-wood really functions uniformly with the sap-wood in these moisture movements cannot be answered until a series of some heart-wood trees has been examined.

Although this paper has been written from the more practical and utilitarian side, yet the new facts brought to light give rise to not a few points of scientific interest. The leafless periods in the deciduous tree's life-history are usually referred to as the dormant periods. The aptness of the term "dormant" cannot be questioned, but when it is used, as it often is, to convey the meaning of inactivity it is quite wrong. Can these activities of the dormant period be explained on purely physical grounds? Why the recurring wave-like shape of the graphs? What part does the water which is involved in starch-hydrolysis play in the results as given? Why the extremely low moisture percentage in March of the younger two years' wood, with such large percentages just behind that region? Since I first became cognisant of these winter activities in *Acer* I have wondered whether they may not help us to understand better the reasons for the plan, and more especially the arrangement of the various pits on the different tissues. Up to now explanations have always been looked for in the leaf-bearing state. Is their chief function to control summer or winter movements? Or do they function equally in both?

In conclusion I wish to express my indebtedness to those who have helped me throughout this work. Professor Balfour, F.R.S., Regius Keeper, Royal Botanic Garden, has more than encouraged me to proceed with the investigations by the very liberal way in which he has placed at my disposal any available material which would aid the investigations. To Mr R. L. Harrow, F.R.H.S., Head Gardener, Royal Botanic Garden, I am also deeply indebted for the painstaking way in which he carried out the details of felling and other operations. Mr Spiers (of Messrs Souness & Spiers) has very kindly given immediate attention to the sawing off of the transverse cuts of several of the trees. To my colleague, Mr H. F. Tagg, F.L.S., I am also indebted for his very helpful criticism, whether constructive or destructive. To Miss L. Snelling I owe the preparation of the original coloured drawings of Plates CL-CLIV.

LIST OF PLATES (CL-CLIX).

Illustrating Mr Craib's paper on Moisture Spread in *Acer Pseudoplatanus*.

PLATE	CL.—Average moisture distribution in bole in	October.
	CLI. ,, ,, ,, ,,	December.
	CLII. ,, ,, ,, ,,	January.
	CLIII. ,, ,, ,, ,,	February.
	CLIV. ,, ,, ,, ,,	March.
	CLV.—Moisture distribution throughout trunk in	October.
	CLVI. ,, ,, ,, ,,	December.
	CLVII. ,, ,, ,, ,,	January.
	CLVIII. ,, ,, ,, ,,	February.
	CLIX. ,, ,, ,, ,,	March.

Explanation of Coloured Plates (CL–CLIV).

These coloured plates, it must be borne in mind, are purely diagrammatic. The colour scheme adopted, a copy of which is found below each diagram, is as follows :—

Moisture content under 60 per cent. of the dry weight of the wood—blue.

Moisture content from 61–80 per cent. of the dry weight of the wood—yellow.

Moisture content from 81–100 per cent. of the dry weight of the wood—grey to black.

Moisture content over 100 per cent. of the dry weight of the wood—red.

By the use of different shades of these four colours a nearer approximation to the actual moisture percentage can be shown ; in all four colours the deeper shading indicates a higher percentage, the lighter shading a lower.

Soon after leaf-fall (in October) the average moisture distribution, as seen in a transverse section from about the middle of the bole, is as shown in Plate CL. From the colour scheme it is readily seen that by far the larger portion of the section has a moisture percentage of 61–80, as indicated by the large area coloured yellow. The youngest wood—on the extreme outside—has a percentage of almost 80, and the moisture diminishes from this zone to its minimum for the whole section. This minimum occurs at about 5 mm. from the outside of the plate, as indicated by the blue circle denoting a moisture percentage of just under 60. Inside this minimum there is a gradual rise towards the centre, as shown by the more intense yellow, until near the centre, where there is a sudden rise from 81 to 100 per cent. (grey to black), which again is continued to well over 100 per cent. in the very centre (red).

In December (Plate CLI—which represents likewise the average moisture distribution in a transverse plane at about the middle of the bole) shades of yellow, indicating a percentage of 61–80, still predominate in the whole section. The very youngest wood—on the extreme outside—has here a slightly lower percentage than is found in October, and the percentage decreases inwards to about the same minimum region—about 5 mm. from the outside of the plate,—as noted in the previous plate. Near the centre we find the same steep rise to well over 100 per cent. (grey and black succeeded by red), but the area over 100 per cent. (red) is now considerably larger than in October ; and, moreover, it will be noticed that within this red area the highest percentage, as indicated by the deepest shading, is now some little distance from the actual centre. As compared with the preceding plate, it will be noticed that the area bounded by the minimum near the outside and the sudden rise near the centre no longer shows a gradual increase inwards, but is broken up into a series of zones of secondary maxima and minima, with percentages, however, nowhere above 80.

By January (Plate CLII—which again represents the moisture distribution in a transverse section from mid-bole) conditions have been considerably altered, as shown by the very different appearance of the diagram. The dominant yellow (61–80 per cent.) is now replaced by grey and black (81–100 per cent.). The radiation of the moisture outwards from the centre has resulted in the very centre being below 80 per cent. (yellow), in the red zone (over 100 per cent.) being very much reduced, and in the larger yellow (61–80 per cent.) area of the previous two plates being now mostly grey to black (81–100 per cent.), the two larger 81–100 per cent. areas (grey to black) being separated by a zone of yellow (61–80 per cent.) in the middle. The extreme outside has here a slightly lower moisture percentage than the corresponding region in December, and, as in the remaining plates (CLIII, CLIV), shows an increase inwards instead of a decrease, as in Plates CL and CLI.

The diagram for February (Plate CLIII), illustrating in the same way the distribution of moisture at mid-bole, shows that in the interval the radiation of the moisture outwards from the centre has continued. This diagram bears the same relationship to Plate CLII that Plate CLII does to Plate CLI. Whereas in Plate CLII the bulk of the moisture was still not far from the centre, this central maximum is decreasing, and the moisture is reappearing as a maximum towards the periphery. For the first time we find red (over 100 per cent.) appearing in the outer region.

In the diagram for the moisture distribution in a transverse plane at mid-bole in March (Plate CLIV) we find that the horizontal spread has now gone so far that we have really almost the reverse of the conditions depicted for October (Plate CL). The lowest percentage recorded here is in the centre, which is below 60 per cent. (blue). Excluding the youngest wood, we had in October a gradual increase inwards from 60 per cent. to 80 per cent., and then a sudden increase from 80 per cent. to well over 100 per cent. in the very centre, whereas here, in March, we find a gradual increase outwards from below 60 per cent. at the very centre to 80 per cent., followed by a more marked increase from 80 per cent. to over 100 per cent. From this zone of over 100 per cent. (red) there is a sudden decrease to

80 per cent., and then a more gradual decrease to almost 60 per cent. The zone occupied by this black, grey, and yellow colouring denoting the decrease from 100 per cent. to almost 60 per cent. would correspond roughly to the area between the minimum noted for October (Plate CL) and the outside.

Plates CLI, CLII, and CLIII show intermediate stages in the moisture spread. Probably the best impression of what occurs in the way of moisture spread during the period under survey will be obtained from a comparison of the two extremes, as represented by the diagrams for October and March (Plates CL and CLIV respectively). The maximum region in October becomes the minimum region in March, and the minimum region of October becomes the maximum region of March: or, in terms of the colours depicted, red, indicating a moisture percentage of over 100, occurs in the centre of the trunk in October and in March only towards the periphery; blue, indicating a moisture percentage of less than 60, occurs in the centre of the trunk in March, and in October it occupies a circle roughly about 5 mm. from the outside of Plate CL.

Explanation of Graphs (Plates CLV–CLIX).

Whereas the coloured plates have been designed to show the average moisture distribution as seen in a transverse plane at approximately the same level in the bole of each of the trees examined, the graphs drawn on mm. paper give the actual results of the various experiments, and show the state of the moisture distribution throughout the trunk at the selected levels.

In each case metre distances above ground level are marked off vertically along the median line of the plate, and the centre line of each transverse cut examined is inserted in conformity with this scale according to its distance above ground level, as ascertained when the tree was felled.

In Plate CLV each graph read horizontally gives the moisture distribution at that particular level from the youngest wood at the left-hand side of the plate to the centre of the trunk in the middle of the plate. In the remainder (Plates CLVI–CLIX) we have, read horizontally, the moisture distribution from the centre of the trunk in the middle of the graph to the outside of the trunk in two directions at the extreme right- and left-hand sides.

The annual rings have been plotted horizontally (2 mm. = 1 year) and the moisture percentages vertically (1 mm. = 2 per cent.), so that an upward tendency of the graph signifies an increase in moisture percentage at that place, a downward tendency a decrease. Further, the nearer the line approaches the vertical the more sudden is the increase or decrease, the less the line departs from the horizontal the more gradual is the increase or decrease depicted.