If N is prime, it is expressible as the difference of two squares in only one way, viz. $\{\frac{1}{2}(N + 1)\}^2 - \{\frac{1}{2}(N - 1)\}^2$. To prove that N is prime by this method, the number of additions required is $\frac{1}{2}(N + 1) - n$, which is $\frac{1}{2}\{(n - 1)^2 - r_0\}$.

It may be noticed that when $n + m$ and r_m have a common measure, it must be a factor of N, and the additions need be continued no further.

For example,

$$\begin{array}{rcl} & N = 8131, & n^2 = 8281. \\ n = 91 & & r_0 = 150 \\ & & \underline{183} \\ n + 1 = 92 & & r_1 = 133 \\ & & \underline{185} \\ n + 2 = 93 & & r_2 = 518 \\ & & \underline{187} \\ n + 3 = 94 & & r_3 = 705 \end{array}$$

94 and 705 have a common measure, 47; therefore 8131 is is divisible by 47, and the other factor is then found to be 173.

Mr. Busk's method of shortening, exemplified on p. 414 by his proof that $73 = 37^2 - 36^2$, depends upon the following:

Let $r_0 + 2mn + m^2 = (k + m)^2$, then $m = \frac{1}{2}(k^2 - r_0)/(n - k)$: since $k^2 - r_0$ is even, k is even or odd according as r_0 is even or odd; it is necessary only to try values of k descending by differences of 2; the greatest possible number of operations is $\frac{1}{2}(n - 1 - k_0)$, when k_0 is the value of k, with which we begin.

The process may conveniently be arranged as in the following example:

Let $N = 6667$, $n^2 = 6724 = 82^2$, $r_0 = 57$.

k		$82 - k$		$\frac{1}{2}(k^2 - 57)$		Quotient.
15	...	67	...	84 32	...	a fraction
17	...	65	...	116 36	...	,,
19	...	63	...	152 40	...	,,
21	...	61	...	192 44	...	,,
23	...	59	...	236	...	4

therefore $6667 = (82 + 4)^2 - (23 + 4)^2 = 113 \times 59$.

If N is composite, this method is not always shorter than the former. It will be shorter whenever $2m > k - k_0$, but it is not easy to see how to determine *a priori* whether this is the case.

The method by decreasing squares is not one of general application. For instance, the factors of 323,171 cannot so be found. It is the difference of two squares, each more than ten times as large as the first square used.

W. H. H. HUDSON.

King's College, London, March 15.

Dolomedes fimbriatus, Clerck, at Killarney.

IT may interest some of your readers to know that this rare and fine aquatic spider occurs on Cromaglaun Mountain, near Killarney Lakes. I first found it when collecting the little shell, *Limnæus involutus*, and though I had it two or three times in my hand, it was so active that it escaped, and I, not knowing its powers of diving, never thought of looking for it under water. The following year I again visited the little lake, which is called Crincaum, with some friends, and this time we fairly captured the spider, which I then easily identified as *Dolomedes fimbriatus*. There is a good account of it in Blackwall's "British Spiders," and also in Andrew Murray's "Economic Entomology—*Aptera*," but I am not aware that it had been observed in Ireland before I found it.

A. G. MORE.

March 18.

BEECH-WOOD.

IT is so characteristic of the science of to-day to find specialists narrowing their field of research, and confining their investigations to a deep narrow channel, that no surprise can be felt that two able men should devote their energies for two years to the examination of the biology and chemistry of the wood of a single tree. It is not so easy to avoid astonishment at the results of the two years' work, however, appearing as they do in the form of a large book[1] of 238 pages of close description and argument, interspersed with long tables of figures, abounding in interesting information when properly read.

The authors have divided their work very fairly, the botanist having set himself the task of elucidating in detail the histology of the wood, the distribution of water, starch, and other contents, the formation of annual rings, and the growth in thickness of the trunk, and a number of other problems throwing light on the growth of the beech in the forest; while the chemist has confined himself to the task of analyzing the timber, so as to discover (1) the quantities of total ash, water, nitrogen, &c., in different parts of the tree; (2) the percentage composition of the ash, and the manner of distribution of the individual constituents; (3) the absolute quantities of each ash-constituent in 1000 parts, and other chosen quantities of dry substance of the wood; (4) the annual in-take and out-put of these constituents on a hectare of beech forest; and (5) similar particulars for the nitrogenous constituents.

The authors have by no means spared their trees. It is enough to make one envious to read of the trees cut down at all ages from 15 to 150 years, and of the specimens selected at all heights from each; how the research was extended to good, bad, and indifferent soils, and how trees in shade and in the open, trees entire and trees pruned, &c., were all laid under contribution as required. More than 100 stems of all ages were thus employed.

The manner of utilizing this enormous mass of material is worth noticing, for every kind of determination was made that would yield practical information.

The height of the trees was found, as the best indication of the value of the situation; the number of stems on a given area, their surface, contents, &c., were also determined; the age of the trees, their physiological condition, &c., were all considered in due course. The selected stems were then cut up as follows: transverse disks were cut at the successive heights of 1·3, 5·5, 10·7, 15·9, 21·1, and 26·3 metres, and separate determinations made of the specific gravity, histological peculiarities, analysis, &c., and these not only for wood and cortex separately, but also for each 30 annual rings of the stem. The thickness, density, &c., of the annual rings were also tabulated, and attention paid to north, south, east, and west sides of the stem.

Not only are all these data given in detail in the tables, but other tables are provided showing the mean densities, cubic contents, &c., &c., of whole trees, or of the trees on given areas; and the patient compilation and ingenious methods here displayed reflect the greatest credit on the authors. It is, in fact, especially in the application of their measurements, &c., to the forest as a whole that the tables will find their greatest practical value. There is also much of more abstract scientific interest to be learnt from the results.

On examining the histology of the wood, several new facts were discovered. The curious dipping in of the annual rings where they cross the broader medullary rays, and the deposits of grains of calcium carbonate on the septa of the vessels, may be mentioned by the way; but the most important results are those relating to the length of the elements, the lumina of the vessels, and the relative numbers and distribution of the latter on a square millimetre of transverse section.

The wood of the beech consists of the usual elements—vessels, tracheides, libriform fibres, and wood parenchyma, with transitional elements difficult to classify under any one of these heads. As was long ago pointed out by

---

[1] "Das Holz der Rothbuche," by Profs. R. Hartig and R. Weber (Berlin: Springer, 1888.)

Theodore Hartig, Sanio, and others, the length and breadth of the various elements differ in different parts of certain trees. Prof. R. Hartig has now worked out this subject in the beech for the first time, giving long lists of measurements at various heights, ages, &c., as before.

The recent vessel-segments, tracheides, and fibres in a five-year-old beech-tree are only half as long as those in a tree 120 years old, and this occurs in what at first sight appears a very curious and inexplicable manner.

The length of these organs at first rapidly increases, until the tree is about 60 years old; then they either no longer show increase in length, or do so very slowly, till the tree is about 120 years old. They then exhibit their maximum length. Henceforward the elements formed are shorter each year, and much so if the tree is growing free in the open.

Moreover, in the same tree, the longest elements occur at the base of the trunk, and shorter and shorter ones occur up to a height of about 5·5 metres; then the tracheides and vessel-segments are found to be longer again, until the height of 15·9 metres is attained. The lengths are much less in the crown. The libriform fibres decrease regularly in length all the way up.

Hence, put generally, the elements are short in young trees and in the upper (*i.e.* youngest) parts of older ones; their lengths increase afterwards year by year, but after 120 years only shorter and shorter elements are again found.

The lumina of the vessels also vary with the age of the tree and with the height of the part. Taking, for example, the vessels at a height of 1·3 metres, the average diameter is 0·05 millimetre during the first 30 years, but between 30 and 60 years they are larger (0·064 millimetre), and maintain this average afterwards to the end of the life of the tree. Still more striking are the changes at different heights in the tree: both in very young and in very old trees the vessels in the crown may be very narrow indeed compared with those elsewhere.

As facts of great importance in its bearing on the question of the specific gravity of wood, and the futility of comparing rough weighings, we may select the following. The three elements—vessels, tracheides, and libriform fibres—are distributed very differently on the transverse section of the annual rings according to the age of the tree and the level of the section. The rule is that, at the same level, the number of vessels per square millimetre increases as the tree ages. When it is shown that the numbers may range between about 60 to 80 at 30 years, and 200 to 220 at 100 years or more, the conviction arises that the question of specific gravity may be complicated by many factors.

As regards the level of the section examined, the rule is that the number of vessels per square millimetre increases as we go upwards. But it is found that the number of vessels in any one annual ring remains about the same: it is differences in the breadth of the rings which cause the close packing or otherwise, and the general tendency of the rings to be narrower upwards explains the above.

With respect to tracheides and fibres, it may be said generally that young trees form few tracheides (and chiefly near the vessels) but more are formed later; but again, in old age, in the open, the tracheides are replaced by fibres.

Some interesting observations follow on the microchemistry of the wood: vanillin and coniferin occur in the walls of the wood elements, and it is somewhat remarkable that they should show a cellulose reaction quite late. Relatively small quantities of tannin are found in the cells, and drops of "wood-gum" are abundant. It is interesting to note the infiltration of the walls with tannin, and this gives the deeper colour to wood exposed to air, owing to oxidation.

The dark (false) heart of the beech is not due to the presence of much tannin, and Hartig again insists that this wood cannot be divided into heart-wood proper as distinguished from sap-wood. The false heart is a pathological production, and nearly always contains Fungi.

But perhaps the most interesting facts in this connection are those bearing on the starch-grains and their movements.

In an old beech-tree, the quantity of starch diminishes from the periphery to the centre: little or none is found within the last 50 annual rings. In the winter the outer rings will be crowded with starch, every cell of the wood-parenchyma and medullary rays being full.

It is, of course, impossible to go into the details of Hartig's experiments and measurements, but he found that under ordinary circumstances the main mass of stored-up starch does not move at all: contrary to the received opinion that the starch is all, or nearly all, dissolved in early summer, and stored up again in autumn, the astonishing fact comes out that during the development of the current year's annual ring, the cambium only takes starch from the next inner ring (and sometimes the next but one) in June and July, and that before the middle of September it is all restored.

In other words, only the two preceding annual rings yield starch to start the cambium: the completion of the new ring, its stores of starch, and the restoration of the borrowed starch, are at the expense of the work of the leaves of the current year.

Light is thrown on the subject by the following experiment—an admirable instance of the progress which is being made in the study of the physiology of plants. Two trees were completely deprived of branches and leaves, and then allowed to stand otherwise untouched: one was felled at the end of twelve months, the other at the end of two years. In both cases it was found that during the first year after the mutilation a new ring was formed by the cambium, but the mass of wood in this was only about 5 per cent. of the normal increment which would have occurred if the tree had remained intact: no trace of further increment was observable in tree No. 2 during the second year.

This 5 per cent. increment was at the expense of all the starch stored in the medullary rays and wood-parenchyma of the stem; in other words, the quantity of starch held stored in each of these trees was equivalent to the quantity of woody substance in a ring containing 5 per cent. of the normal annual amount: in other experiments the amount rose to 15 per cent. or more, but never approached that of a complete normal ring. It is noteworthy that the cambium only acquires the power to attract the whole of this stored starch under such special conditions of hunger as are induced by stopping its supplies from the leaves.

Some similar experiments, with modifications in the special cases, led to the result that the starch which comes down from the leaves—even when only sufficient to partly fill one layer of wood—is rapidly distributed *over the whole sheet of wood*, both above and below.

The question, What are the stores of starch for, if not to feed the cambium? is answered by the following. Weber's analyses show that the nitrogenous substances decrease from without inwards in the wood, just as does the starch in a normal tree; but the total proteid substances remain practically unaltered (at least they suffer no diminution) because they are not used up in building the cell-walls. Any drain on the proteids by the cambium seems to be paid back in due course by the travelling of the proteids from cell to cell.

Now it is a well-known fact that the beech, like other similar forest trees, only yields seed after attaining an age of 50 to 60 years, and that what are termed good seed-years are separated by considerable pauses. It is also well known that the production of fruit and seed "exhausts" the plant: in the case of annuals it completely drains their resources, and every apple-grower knows that the trees need "rest" after a good crop. In view of all the facts, then, it is most probable[1] that the stores of starch in the beech are put up in reserve for the enormous drain which the "seed-year" will involve, and we shall see that this idea is fully borne out by the chemical analyses, which show that certain valuable minerals are similarly stored for the seeds.

But this does not fully explain why the stores diminish inwards. Two causes are adduced for this. In the first place, a seed-year having exhausted nearly all the supply of starch, we have seen that succeeding deposits only occur in the outermost rings of wood, and so there is no restoration of the deposits deeper in the tree; secondly, some of the stored starch in the deeper layers gradually undergoes change into the drops of "wood-gum" (*Holzgummi*), of which mention was made above.

Some "practical results" of the above may now be noted, the most important being that the difference in weight between wood felled in summer and that felled in winter is, in effect, *nil*, contradicting a wide-spread assumption, and confirming a doubt which Nördlinger had already put forward. It thus follows that the want of durability in summer wood depends on other causes, and Hartig considers it due to the fact that winter wood has time to dry on the outside before the atmospheric influences are favourable for the development of Fungi, the spores of which are always about, but dormant in the cold of winter. No doubt there are other factors to be considered also, but the importance of the above has been too much overlooked or under-estimated.

Another interesting section of the work is that dealing with the formation of the annual rings. By cutting disks at equal distances apart on simultaneously-felled trees of 50, 100, and 150 years old, and measuring the breadth, &c., of the rings at eight points round the disks, some further discoveries were made. Generally put, it was found that (in the case of beeches near Munich, at any rate) the annual ring commences to form at about the end of May, the tree being already in full leaf; by the middle of June the ring is one-third its normal breadth, and is half finished early in July, attaining its normal complete state before the end of August. Hence the whole period of the activity of the cambium only amounts to about two months and a half.

As regards the parts of the tree, it is found that the active division of the cambium commences first in the twigs and small branches; it is later in the trunk proper, and begins at different parts, according to circumstances.

In the oldest trees (150 years) the cambium was found in an active state at 3 to 4 feet up, while parts above and below were still dormant; whereas in somewhat younger trees the process of ring-formation began simultaneously all up and down the trunk. In still younger trees the cambium was found to awaken first in the higher parts of the trunk. More investigation is still needed here, however, before several dark points can be regarded as explained.

Some generalizations as regards the growth in thickness of the beech deserve notice. In the crown, the annual increment—*i.e.* the quantity of wood produced by the cambium during one period of its activity—increases more or less rapidly as we proceed from the tips of the branches to their point of origin from the trunk; but this is by no means the case in the trunk itself, and several cases have to be considered.

In those trees which, owing to close crowding in the forest, have developed only feeble crowns, the annual increment is greatest just beneath the crown, and diminishes regularly downwards; and in very closely crowded trees the cambium in the lowermost parts of the stem may even *stop dividing altogether:* in such cases the ordinary mode of ascertaining the age of the tree would yield false results, for the number of annual rings at 3 to 4 feet high is less than the number of years of the tree's life. The physiological meaning of the above is, that the small leaf-area does not supply sufficient food-material to provide for the needs of the whole sheet of cambium, and the upper parts take all that is sent down, leaving none for those below.

In those trees which have well-developed leafy crowns, more exposed to light and air, the annual increment follows a rule exactly the converse of the last—the amount of wood formed per annum is greater as we proceed from the upper part of the stem to the lower. If we leave out of account the lowermost 6 to 12 feet, every gradation can be found, and in rare cases the breadth of the annual ring may be constant from above downwards.

Now comes in a remarkable discovery. If such trees as the above are suddenly exposed to full light and air, &c., by cutting down the neighbouring trees, the annual rings *in the lower parts of the stem* suddenly become much broader: no such stimulation of the increment occurs in the upper parts.

Now as to the explanation of these remarkable phenomena. There can be no reasonable doubt that the precedence shown by the upper parts of crowded trees is due to the rapid warming which they receive from the air in the spring sunshine: the lower parts of such trees, however, have to wait until the water which they absorb from the soil raises their temperature to the minimum cardinal point, and by the time the water of the soil is sufficiently warm for this, the cambium in the upper parts is far ahead, and working under such favourable circumstances that the rings maintain their greater breadth to the end. But the chief factor in the process is that the upper cambium gets the first supplies of food-substances, and in larger quantities, because lower down the diminished supplies have to spread over a larger area.

In the case of trees exposed freely to the light and air, the sun's rays warm the thinly covered soil (and its water) around the roots, and so the cambium is enabled to recommence its annual work pretty nearly at the same time over the whole stem: in this case thicker rings in the upper parts of the stem must be due to the nutrition being more abundant. All this still fails to explain the *sudden* stimulus to the annual rings in the lowermost parts of suddenly isolated trees, and Hartig suggests that the probable cause is an increased supply of potassium salts and phosphates, rendered available at the roots. This of course implies the further assumption that such minerals are employed directly, and however probable this may be, it is by no means proved.

The removal of branches from the tree leads to the same results as crowding, *i.e.* the rings formed below are thinner, because the supplies are not sufficient to feed the sheet of cambium equally from above downwards. Moreover, the complementary case may occur: a tree in the open may have *too many leaves*, as is proved by the fact that it may be pruned without any loss of increment. The leaf-area of a tree is by no means always proportional to the supplies of food-materials from the soil: it may be too large or too small to be working economically, or so large that each leaf is sluggish—lazy, so to speak, and not doing anything like the amount of work it is capable of. Not only is this idea interesting and suggestive in itself, but it has important bearings on the question of the thinning and treatment of forests generally.

We must leave this topic, however, and pass to one of a different nature, but no less scientifically important. This is the weight of the wood. Although certain practical ends can be roughly attained by merely weighing equal-sized blocks of any particular kind of timber, at any time or in any state, it is, nevertheless, easy to see that such

---

[1] Hartig has since proved that this explanation is the correct one (*Botanische Zeitung*, December 28, 1888, p. 837).

weighings are of little or no scientific value: only the weight of the fresh timber immediately it is felled, and the absolute dry weight (after exposure to 105° C. long enough to drive off all moisture) yield results of really scientific value.

If we regard 1 cubic metre as the unit of volume, we may obtain some useful factors by ascertaining the weight of dry woody substance in such a volume, from different parts of the tree, and from trees grown under different conditions, &c. The amount of water driven off, *i.e.* the difference between the fresh weight and the absolute dry weight, is found to vary much, and Hartig some time ago obtained most valuable results, bearing on the difficult question of the ascent of water in tall trees, by comparisons of this kind. Moreover, the real test of quality of wood—its value as fuel, and other technical properties—is given in the absolute dry weight.

Passing over the methods, and other details, it may next be pointed out that the weight of a given volume of wood depends chiefly on the sizes and distribution of the histological elements—vessels, tracheides, fibres, &c.—and in the case of beech-wood, it is especially the sizes and numbers of the vessels that have to be taken into account, and as these stand in direct relation with the magnitude of transpiration, it is clear that the quality of the timber as estimated by its weight depends on the quantity of leaves.

Neglecting the roots, we may regard the tree as consisting of three parts: the stock, the shaft, and the crown. Now, the root-stock and the crown contain wood of the best quality, and some curious results come out on examining why this is.

As is well known, the base of the tree widens at the origins of the main roots, and here the annual rings are broadest: if we bear in mind that the number of vessels in each annual ring remains constant, it is easy to understand why the wood is better—it is simply that the vessels are dispersed over a larger sectional area, and are separated by more numerous fibres, the elements which give solidity to the wood.

We have seen that in the trunk of a tree with a large crown of leaves, the mass increment increases from above downwards: this means that the same number of vessels (per annual ring) are distributed over a smaller sectional area above. In a given case, on 1 square millimetre of area, there were 115 vessels at a height of 1·3 metre, but at 10·7 metres height there were 175 vessels on the same area; hence the latter was lighter and worse wood.

By thus counting the number of vessels per square millimetre, and taking the average size of the main vessels, it was possible to get an expression of the relative area occupied by the lumina, and that of the rest of the annual ring; of course this is only approximate.

It comes out that, in trees with large crowns, while the number of vessels is the same at all heights in the stem, the number of vessels *per square millimetre* is much fewer below than above.

In the crown of the tree, however, things are very different; the number of vessels in each annual ring rapidly diminishes, because at each branching a number are given off. Thus, where 200,000 vessels were found in an annual ring in the stem, the same in the crown gave only 57,750. This alone would explain the better quality of the wood, but the number of vessels per square millimetre is also found to *increase* in the crown, and this means corresponding depreciation. But the most important factor in explaining the superior hardness, &c., of the wood in the branches is that the average size of the vessels is less, and therefore the area of lumina in the cross-section is reduced.

Physiologically, the reduction in the lumina of the vessels is in relation with the decrease in the volume of water-current as we ascend, and several facts point to the constancy of this relation. It is well known that, if the soil around a tree is suddenly deprived of much of its water, the tips of the tree die off first: "stag-headed" trees are often produced by over-exposure. This is because the average size of the vessels has been adapted for a richer supply of water than comes to them under the new conditions. Hartig says that the average size of the vessels throughout is reduced if the land is deprived of cover, and the tree exposed too much.

As has been seen, the wood of trees below 60 years of age contains fewer vessels, and these with smaller lumina, than afterwards. It is also known that the ascending water-current is confined to the younger outer wood, or alburnum; and if we neglect younger trees, it seems that in the beech it is only the 20 or 30 outer annual rings which conduct the water.

Now the authors of the book referred to find an unexpected relation between the amount of wood produced annually, and the current of water passing up the stem. By an ingenious series of measurements and calculations, it results that much more room is provided for the water-flow in early years than in old age. Thus, a given amount of water, which has for its passage in a tree 30 years old an area of wood expressed by the number 4·04, has only an area equal to 1 64 at 140 years of age. Hence, in order to conduct the larger quantities of water which must pass to the larger crown, the smaller area of wood, in the older tree, has to *increase the number and size of its vessels*, and so the wood is lighter and poorer.

It is impossible here to enter into the bearing of these matters on questions of forest management; it is only a particular case of the dependence of technical forestry throughout on the teachings of science, the principles of which it applies.

An interesting experiment may be quoted. Two beeches 150 years old were felled and examined; they had been completely freed from neighbouring trees 7 years previously. The effect of the sudden exposure to free light, air, &c., was that the mass increment rose to 2·4 times greater than previously, and the weight of the wood formed during the 7 years of exposure was 700 kilogrammes per unit volume, as against 600 kilogrammes previously, *i.e.* 16·7 per cent. more wood-substance was formed. On going into details, it was found that *five times as much wood-substance* was formed each year, and *twice as many vessels* were developed in each annual ring. But since these twice as many vessels were distributed over five times the quantity of wood, the wood was still heavier than that of 7 years previously. On the square millimetre there were 63 vessels, as contrasted with 140.

The reason that letting in the light and air around the tree has such enormous effects is obvious enough to the physiological botanist, but it should also be clear that the knowledge thus obtained is the best guide to such forest practices as thinning and freeing timber: into these matters, however, we do not propose to enter further here, but must pass to other matters. In the section on the course of growth of the beech, an interesting discussion on the limits of height of trees occurs: Hartig regards the chief limiting cause to be the gradual disappearance of the difference in tension between the air-bubbles in contiguous elements: the osmotic forces remain constant throughout, but the lifting power diminishes with age and height, until it ceases to suffice for movement. The influences of etiolation, and judicious crowding, and other devices for timber-growing, are then discussed in the light of what has been already said, and with the aid of numerous tables of close-set and well-classified figures, sufficient illustrations are given to satisfy the most stiff-necked critic of the value of these results.

The chemist's results, however dry they may appear from the tables and curve-diagrams, allow of summary in a way that endows them with an interest to the general reader, no less real than that which attaches to other parts of the work. Methods may be passed over here.

The cortex of course contains most ash, and the quantity of total ash increases with age and with height: these facts have been shown for other trees also.

In the wood proper, the quantity of ash *as a whole* increases from the periphery to the centre, but as we shall see that the distribution of the various constituents is very different in different parts, this generalization will have to be cut up into a series of less general statements. In the same period of growth the total ash increases with the height.

It is somewhat striking that the inner zones of the inner alburnum yield most ash, and thus the central part of the highest transverse section of the stem will contain most ash.

As regards the changes due to age, the ash per cent. decreases till the tree is about 60 years old, and then it increases rapidly for twenty years or so, gradually diminishing again with increasing age. These periods show such close relation to certain facts in the culture of the trees, that they are evidently explained somewhat as follows. During the first 60 years in the plantation, the young beeches crowd one another more and more, and the competing roots restrict one another, and the percentage amount of salts absorbed diminishes year by year: at or about the age of 60 years the trees are thinned by systematic felling, and so more space is given to those which remain, as well as more soil and ingredients from the decomposition of the roots, &c., of the felled trees. The consequence is the increase of ash to a first maximum. At the period about 80 to 90 years the beech has attained the seed-bearing age, and the probability that the diminution of ash henceforth is due to the drain to supply the seeds is too great to be overlooked.

It is interesting to note that shaded beeches, at all periods and in all parts, show a higher percentage of total ash than fully exposed trees, and the same is true of the silver fir (another tree which bears much shading): the trees store up mineral substances, which must be an advantage to them under the circumstances of growth.

If, instead of regarding the total ash, we now look at the constituents, it results that the enormous excess of ash in the cortex consists chiefly of calcium carbonate, from the calcium oxalate (which may form 70 to 90 per cent. of the whole). Much potash, magnesia, and phosphoric acid also occur.

In the wood, the quantity of potassium salts increases from the periphery to the centre; whereas the reverse is the case with the phosphoric acid, sulphur, and magnesia, a fact the more remarkable because the potash usually accompanies the phosphoric acid in other parts of plants —*e.g.* in leaves, &c. It is no accident, however, and the fact comes out that the beech forms large reserve stores of potash (this being the chief cause of the large increase of total ash in the interior of the stem), whereas the phosphoric acid and sulphur travel outwards with the proteids, being repeatedly used in metabolism in the cambium, &c.

We must pass over a number of other peculiarities of the distribution of the ash-constituents, to notice the effect of the age of the tree on the chief salts. The distribution of the potash, lime, and magnesia is little influenced by age, but an extraordinary effect comes out in the case of the phosphoric acid. The young tree starts with a relatively large quantity of this constituent, but the amount sinks year by year till the fiftieth or sixtieth year, and then rises again to about the ninetieth year, to fall afterwards: in fact, the behaviour is similar to what occurs with the total ash, and is doubtless to be referred to the same causes.

Another curious result comes out in studying shaded trees: whereas they take up as much potash and lime as exposed trees, their magnesia and phosphoric acid fall far below those of exposed trees. But the most astonishing discovery is that shaded trees *take up four times as much sulphur* as exposed ones. The analyst himself notes how astounding this is, but he insists that a second series of analyses gave confirmatory results.

Another queer fact is that the kind of soil exerts little influence on the analyses; though a similar conclusion has been come to with other plants.

The study of the absolute quantities of individual ash-constituents in 1000 parts of the dry substance brings out some interesting and important generalizations, which are expressed in the form of curves, and fully bear out in detail what has already been stated.

The quantity of ash and of each ash-constitutent in 1 cubic metre of beech-wood at various ages, as compared with the wood of other trees, is next investigated. The results show that the beech takes more potash than most trees except the *Robinia*—for instance, at 40 years it contains more than four times as much as the spruce fir.

As regards phosphoric acid, the beech and oak need more than other trees, beech-wood at 40 years old having seven times as much as spruce at the same age. With lime the facts are similar: beech needs much more than conifers.

From the whole of the preceding, it is possible to put together some ideas on the quantity of ash-constituents per acre needed for beech forests, and some interesting tables and curves are given in this connection; the return of minerals to the soil in the leaf-fall, &c., is also considered. Perhaps the most important conclusion come to here is that the increment in dry weight of the tree is nearly proportional to the up-take of potash, whereas the up-take of lime is the same—gradually increasing to old age—whether the wood is good or bad, and whatever the nature of the soil. The nitrogenous substance in beech-wood behaves very like the phosphoric acid, in that it diminishes from the tenth to the sixtieth year, and then ascends to a second maximum as the tree reaches 80 years old; and again, the cause is to be found in the influence of the thinning, and in the demands on the reserves when the tree begins to bear seed.

As in all trees, there is of course most nitrogen in the twigs and buds, and in the finer roots. Beech and oak need more nitrogen than other trees, and (so far as the wood goes) the conifers need much less. The total quantity of nitrogen taken up by the beech at 6 years old, in fully stocked plantations, is calculated to be 39·43 kilogrammes per hectare, and this rises to 389·63 at 60 years, and 896·50 at 130 years.

Calculations as to the quantity of nitrogen needed annually per hectare to produce the known yield of wood are then given, and again we meet with the rapid loss after about 90 years, due to seed-production. To these are added estimates of the nitrogen removed in the thinnings, and of that restored in the fallen leaves. All things considered, the quantity of nitrogen concerned annually varies with the age, but at the critical period of 50 to 100 years it amounts to something like 60 kilogrammes per hectare *per annum*.

It is unnecessary to point out further the extreme importance of such investigations as these: it is only in proportion as a nation is armed with statistics based on careful researches like these that it can form any conclusions worth having as to the future value of its forests and the technical merits of those administering them. As to their "practical" bearings, the results speak for themselves: if this is not allowed to be practical science, we may indeed ignore the cry.

H. MARSHALL WARD.

SPECTROSCOPIC RESEARCHES AT THE NORWEGIAN POLAR STATION.

PART II. of the Report on the results obtained at the Norwegian Polar Station at Bossekop in Alten (in connection with the International Polar Investigation,