conical heaps of stones, while others are laid quite flat and are surrounded by a circle of larger stones; a third kind exhibit a primitive art of stone-cutting, the stones bearing a distant resemblance to the human body. Frequently around the graves the bones of horses which had been brought as sacrificial offerings, were found, as were also certain Runic inscriptions.

M. ADRIANOW, in his journey through the Altais, notices the existence in these regions of immigrant communities which have been forgotten and which have been re-discovered by chance. It is also reported from St. Petersburg that a similar discovery has been made elsewhere in Siberia. In the course of a prolonged inspection of his province, the Governor of Irkutsk (Governor-General of Eastern Siberia?) came across a town called Ilim, with 500 inhabitants, 150 houses, and four ancient churches, with remarkable relics of Cossack times. It is still under the republican rule of a *vetche*, or public assembly, convoked by a bell, as in old Novgorod the Great, although the new municipal institutions were supposed to have been applied to that part of the Empire ten years ago. Not one of the inhabitants can read or write.

AN important geographical work on Austro-Hungary is now being produced in parts by Mr. Alfred Hölder, the publisher, of Vienna. The author, Prof. Umlauft, gives in alphabetical order the names of the various States and peoples of the Austro-Hungarian empire, as well as those of the more important districts, mountains, rivers, and towns, with their meanings. He does not, however, confine himself simply to present names, but also gives the forms employed formerly and the various changes which the name has undergone from the earliest times down to the present day. The work is thus historical and philological. The total number of names treated will be between six and seven thousand. The first part, which has appeared, contains 1041 names, from Aa to Donau. Geographical names, it is said, not only have their history, they are themselves pieces of history. The distinction between the German and Slav names of places is characteristic. The great majority of the German village names are connected with those of persons, probably the founders or original owners, more rarely with that of the patron saint. Thus Simmering comes from Simoning, Hütteldorf from Utendorf, Hadersdorf from Hadrichsdorf, Kalksburg from Chadalhohisperg (*i.e.* mountain of one Chadalhoh), Domsdorf from Dominiksdorf. The change wrought in course of time in some names has been very great, and renders their explanation difficult. The Slav names, on the other hand, are mostly taken from the position of the place or some peculiarity in the neighbourhood. They also manifest great stability of form, and it is only in their Germanising that they have materially altered. Thus the Czech Brloh becomes in German Bierloch, Ratibor Rothwurst, and Radoina Rothweim. The Czech Lhota, which means simply a settlement which is free from taxation, assumes in German such various forms as Oehlhütten, Elhotten, Ellgoth, Wellhotten, Welhütten, Wellhütten, Mehlhüttel, Malten, and others. Even real German names have undergone the same eccentric change, and names which in their original form are quite clear in their meaning have by a slight change become incomprehensible; thus Donnersmark is really Donnerstagmarkt, or Thursday Market. It may be remembered that some articles in the *Times* during the autumn, followed by a long correspondence, did much interesting and valuable work of this kind for English place-names, though of course in a less regular and systematic form.

MR. IM THURN's Roraima expedition left Kalacoon on October 16 with three boats and crews of seventeen Pomeroon and two Mazarooni Indians, and on the following day they ascended the first falls of the Essequibo. Simultaneously with their departure from Kalacoon, an expedition for Roraima, under the charge of a commercial botanist named Siedel, left Bartica for Roraima *viâ* Mazarooni. The two parties will probably meet on the mountain.

M. AYMONIER, a Saigon official, has recently returned from a journey of exploration in Indo-China. He left Saigon at the end of September last year to explore Southern Laos, and made a collection of the ancient Cambodian inscriptions. Having explored the intervening country, he reached Bangkok at the end of June last, and here he remained for some time to complete his studies on the Siamese kingdom. The result of his travels will shortly be published in the "Excursions et Reconnaissances," and he will afterwards proceed on another journey of exploration in Annam.

ROOTS[1]

IN treating of the roots of plants this evening, I may request you to dismiss from your minds any expectations or apprehensions of marvellous descriptions of tropical or rare roots on the one hand, or of a list of the peculiarities of various kinds of roots or so-called roots on the other, though it is not improbable that some of the facts will be, in part at least, new to some of you, as they certainly are to many people. I do not propose even to put any new discoveries before you. It has seemed much more to the purpose to show, as well as time will permit, that a vast amount of interesting and important information can be derived from a proper and systematic study of the roots of a common plant—information, moreover, which is important alike to the scientific botanist and to the practical agriculturist, two people who find they have more and more in common each day they come to know one another better. As the diagrams must in part have told you already, I propose that we meet on ground familiar, to a certain extent, to every one; and the sequel will show, I hope, that we have in no way acted unwisely in taking each other into confidence on the subject of an ordinary root, such as is well known to all of us. So much is this the case, that our study may be confined for the most part to the root of the common broad bean and a few other plants of our gardens.

[The lecturer then shortly described the germination of the common bean, maize, and a few other plants, and illustrated by diagrams the mode in which the first or primary root of the bean seedling emerges below, as the young seedling shoot (or "plumule") prepares to force its way upwards to the light and air. Next followed a short consideration of what this root may be said to be.] Anticipating matters to a certain extent, it may be shortly described as an organ for fixing the rest of the plant to the substratum, or soil, from which it absorbs certain food-materials. By confining our attention to this typical and well-known form of root, we may avoid any complexities resulting from the consideration of the more extraordinary cases occurring among the lower plants, or among curious aërial epiphytes, parasitic or otherwise, and other abnormal forms—forms which would demand several lectures by themselves.

The roots we have to consider, then, are organs for anchoring the rest of the plant firmly into the soil, and for absorbing certain matter dissolved in water from that soil. Obviously, we may do well to see, first, how the root gets into the soil; and secondly, how it accomplishes its objects when there.

When the young root first peeps forth from between the coats of the seed, it is seen to have its tip directed downwards towards the centre of the earth. Now this is not an accident; for if the seed be turned over, so that the apex of the root is made to turn upwards, its tip soon bends over, and again becomes directed downwards. [Mr. Ward then proceeded to explain, as shortly as could be done without detailed experimental evidence, that this persistent turning earthwards of the young root is due to a peculiar property, almost of the nature of a sensitiveness or perception to the influence of gravitation, and is not due merely to the weight of the organ.]

Next, evidence has been obtained to show that the tip of the root has a slightly rocking or swinging movement, which is more or less of the nature of the movements so well known in the case of the stems of twining plants; the tip of the root, in fact, not only moves earthwards, but tends to describe a very steep spiral as it does so. These successive very slight noddings to all sides of the tip as it proceeds in a line directed towards the centre of the earth are extremely slight, it must be borne in mind, but they may aid the point of the root to wriggle its way between the particles of earth in a loose soil, or to run down any crevice or hole it meets with.

Thirdly, in addition to its determined tendency to descend, though in a very slightly spiral course, the tip of such a root as we are describing has been found to be peculiarly sensitive to the contact of solid bodies. This extremely curious phenomenon could only be fully described by references to experiments and matters which we have scant time for. It must suffice, therefore, to state that there is evidence to show that the *extreme tip* of the root, on coming in contact with a hard resistant body, is caused to turn aside *from* that body, and if it comes simultaneously into contact with two bodies, one of which is harder than the other, it is caused to bend away from the harder of the

[1] Abstract of a lecture delivered before the Manchester Horticultural Society, in the old Town Hall, Manchester, on November 6, by H. Marshall Ward, M.A., Fellow of Christ's College, Cambridge, and Assistant Lecturer in Botany at the Owens College

two. This property is all the more curious because, at a portion of the root a very short distance behind the tip, contact with a solid body causes that part of the root to curve *over* the touching body, much in the way that my finger is now curved over this wooden pointer. As already stated, time will not admit of our examining these very remarkable matters more closely—they form subjects for lectures in themselves.

But we have not yet finished our survey of what these sensitive tips of the roots are capable of. Experiments show that they turn towards a wet surface or atmosphere—a fact of great importance, and one which no doubt lies at the base of the explanation of the choking up of drain-pipes, &c., by the roots of neighbouring trees. Further, the apex of the root of such a plant as the bean we are considering avoids the light—avoids it as energetically as the leaves and green parts turn towards it. The two facts thus tersely put, viz. that the tip of the root tends towards a damp spot and avoids an illuminated one, are of course also in agreement with the rest of the behaviour of our germinating bean, and hence the root descends into the damp, moist, granular soil.

It is now time to see what sort of structure this wonderful root-tip possesses, and to inquire whence comes the impulse which drives it forwards into the soil—for it will be seen that while the forces producing the various curvatures which have been referred to tend to guide the apex of the root downwards between the particles of soil, towards the darker, moister, deeper parts, they cannot be expected to drive it into the soil.

In the first place, the tip is a firm, conical, smooth body, covered with a slippery, loose root-cap, as seen in the diagrams. Now, it cannot be too carefully borne in mind that the true tip of the root, beneath the covering cap, is resistant and somewhat elastic; it consists of multitudes of minute tightly-packed cells, each densely filled with protoplasmic substance containing very little water, and of a consistency resembling in some degree that of a well-made, hard-set jelly. Perhaps, indeed, a better idea of it may be gained if the conical tip of the root is compared to a firm, resistant jelly, cut up by delicate partitions into multitudes of minute blocks, which, however, are not separated from one another at all. In any case, it is clear that such a cone, if steadily and slowly driven by a persistent force from behind, is admirably adapted for penetrating between the particles of soil, especially if we bear in mind the following facts: (1) the cone is protected by a slippery cap of loose cells, which prevents the abrasions of the particles of soil from injuring the cells beneath; (2) the driving force is steady and continuous, and directed vertically, *i.e.* along the axis of the cone; (3) the tip oscillates slightly from side to side, and is thus probably (though not to any very great extent) insinuated between the earthy particles, no doubt being aided to a certain extent by other properties to which allusion has been made. It is of course obvious that the last thing we should expect of such a cone is that it could take up quantities of water from the soil: its structure is clearly in no way adapted for such a purpose, if only from the fact that there would be nowhere for the water to effect an entrance.

And now comes the question, What is this steady, continuous driving force from behind? Well, it is due to the simultaneous elongation of the hundreds of thousands of little cells situated a short distance behind the more rigid cone we have just examined. No doubt it seems a hard fact to grasp—that the absorption of water, and the intercalation of minute particles of substance in the interior of the cells shown in this diagram should be capable of steadily driving the apex of the root into the soil; but it is a fact nevertheless. Perhaps you will apprehend the matter more clearly if I offer you a well-known illustration which, it is true, does not exactly cover all the facts, but which will, at any rate, aid you in overcoming some initial difficulties. You are well aware that a wedge of wood driven firmly into a crack in a rock and then moistened, swells, and that it may swell so powerfully as to fracture the rock; very well, the elongation of the cells behind, which steadily drives the firm cone of the root forwards, is to a great extent due to the absorption of water, which causes each cell to grow longer. I say to a great extent, because, while the water is, on the one hand, absorbed in a slightly different way and enlarges the volume of each cell to a much greater extent, there are, on the other hand, forces at work which cause new particles of substance to be added to those originally composing the cells, and so fix the cells, as it were, in their condition of greater elongation, strengthening them at the same time. But this is not all. Besides growing longer, and thus driving the apex steadily forwards, the cells behind increase in diameter, and so push aside the particles of the soil with a force which would astonish you if I entered into figures; this, however, can only be adverted to here, since we must now pass to the explanation of one or two other points.

It is clear that, great as is the driving force supplied by so many elongating cells—and, of course, it is upon the simultaneous action of countless thousands of cells that the driving power depends—it would soon cease to be of much use unless a holdfast were insured at some point behind. This brings me to the consideration of an extremely important matter, and one on which I hope to make you quite clear. At first, while the root is still very young (as in this diagram), the weight of the seed above, with that of any soil covering it, seems to suffice to afford the necessary points of application; and this will doubtless be supplemented immediately afterwards by the increase in diameter of the upper part of the root.

When the root has attained some little length, however, a striking change takes place in its behaviour to the surrounding soil. First, let me call your attention to the following points, as illustrated by these diagrams. When the young primary root has attained a length of about four to six or eight inches—depending on circumstances which we need not occupy time in examining—the older portion nearest the seed has ceased to grow in length, and its surface is becoming clothed with a dense covering of very delicate hairs, which will be referred to in future as the "root-hairs." Each root-hair is an extremely slender sac—a sort of long tubular bladder, in fact—which possesses in virtue of its peculiar organisation an extraordinary aptitude for taking up water, and for attaching itself to the particles of soil with which it comes in contact. These facts are well illustrated by reference to these diagrams, to which I wish your attention for a few minutes.

From the delicacy of these root-hairs, and from their springing at right angles from the surface of this part of the root, radiating in all directions between the particles of soil, to which they immediately proceed to glue themselves, it is obvious that they are saved from being torn away as the tip of the root is slowly driven forwards between the particles of soil; if they were to arise on the tip itself, or on the parts which are elongating behind it, they would infallibly be removed by the abrasion of the particles of soil. Instead of this, however, they become developed on the parts behind in successive multitudes as those parts cease to elongate.

At the same time, the thousands of points of attachment established by the root-hairs afford the holdfast which becomes more and more necessary as the apex of the root is driven further and further forwards, and as the weight of the aërial parts of the plant, with their increasing surfaces exposed to wind and weather, become larger.

Meanwhile, leaving aside for the moment the consideration of how these millions of root-hairs take up the water and food-matters from the soil, the young root has been making preparations for obtaining a still firmer and wider holdfast on the soil, which will, at the same time, enable them to absorb water and food-materials at millions of new points further and further removed from the centre at which the primary root commenced its operations. To understand this, I must call your attention to this diagram, showing how the branching of the root proper is brought about. In the interior of the growing root a number of cells begin to multiply at certain points, and to form the young beginnings of lateral roots or rootlets; further back you see these young lateral roots upheaving the tissues of their parent root as minute knobs. By this time, however, these portions of the mother root have ceased to grow in length, and thus the tender little tips of the lateral roots can protrude and be pushed into the soil around without danger of being dragged off or injured, as they would inevitably be if this part of their mother root were still actively elongating. Notice carefully the exquisite adaptation to the circumstances, though brought about in a slightly different manner; no time is lost in the preparation of the young root branches within the tissues of the parent root, but the tender tips, as in the case of the root-hairs, only proceed to grow radially into the surrounding soil when the growth of the mother root in a direction across their long axes has ceased.

Time will not allow of our examining these matters more in detail; but I cannot avoid calling your attention to the fact that these lateral roots are sensitive to gravitation in a manner different from the primary root—they grow, not straight down towards the centre of the earth, but across the vertical, it may be more or less inclined, in different cases. In other respects they resemble the primary root generally, in their turn producing root-hairs and daughter roots, which radiate from them in all directions into new portions of the soil, as shown in this diagram.

I need not do more than point out to you that it would be difficult to conceive of a series of adaptations better calculated to insure that the various parts of the root-system come successively in contact with the whole mass of soil traversed; and when your eyes follow mine over this diagram, you will agree that matters have become so arranged, so to speak, between the roots and the soil, that every part of the latter is laid under contribution. Notice how this vertical cylinder of earth is first bored through by the primary root, and then traversed in all directions by the root-hairs, in a wave, as it were, passing from above downwards. Next come the lateral roots, burrowing in all directions from the main shaft, and each in turn demanding toll from the cylinder around it by means of its wave of root-hairs. Then follow tunnelings along the lengths of each of these rootlets, and on all sides at right angles to them, until every nook and cranny has been investigated by these enterprising rootlets and their prying root-hairs. Quite apart from all else, therefore, the root-system obtains a greater and greater holdfast on the soil by driving its tips in on all sides.

But I must now draw your attention to some matters which throw even more light on our subject. The root-hairs, as they develop successively from above downwards on the primary root, or on the lateral rootlets, come into the closest contact with the particles of soil—contact so close and firm, in fact, that they cannot be torn away without injury. There are experiments to prove that their cellulose walls become actually moulded and gummed on to the solid particles of quartz, slate, and other rocks of which ordinary soils are composed, and this diagram shows how we can lift up a relatively large cylinder of soil adhering to the root-hairs of a young seedling.

Now you are probably aware that the sort of soil in which a healthy plant flourishes contains air-bubbles as well as water in the interstices between the particles, and into which the root-hairs become insinuated. Bearing this in mind, you will have no difficulty in understanding from the diagram how the root-hairs absorb the aërated water necessary for their well-being. I need simply make the additional remark that each little bag-like root-hair takes up the liquid water through its permeable walls into its interior, in some respects very much as a bladder full of a solution of sugar or salt would absorb water if placed in it.

But this water taken up by the root-hairs and passed on into the rootlets and so on up the stem (a process for which provisions are made which we cannot go into here), is not pure water; it contains, besides air, certain small proportions of the soluble matters found in all soils. It is, in fact, much like ordinary drinking-water from a well or spring, which always contains some matters in solution. But the roots want certain other minerals, which will not dissolve in pure water to a sufficient extent under ordinary circumstances. Well, the root-hairs, in making use of the oxygen which they, like all other living bodies, require, give off small quantities of acids which aid the solution of these more refractory matters.

And now I have finished—not because the subject is exhausted, but because the time at our disposal is. I hope the object has been attained, and that you fully realise how well worthy of study is a common living root. Not only is it instructive as a simple object of dissection, a subject upon which I have had no time to dwell, but the peculiar properties which stamp it as a living organ themselves afford material for much thought and investigation. When we go further, however, and see how the structure and the functions depend upon one another, some very curious reflections thrust themselves upon us; and if time had allowed us to look at these matters from the other platforms of view—to see how old errors have gradually been explained away on the part of observers, and how what may be called improved adaptations have arisen in the evolution of the root as an organ—these reflections would have obtained in depth. But we have taken a glimpse at matters still more comprehensive: we have touched upon that important question of the relation of the root to its physical environment, and it is not difficult to see numerous points where the struggle must have been intense before the plastic substance of the root was enabled to meet the requirements necessary before it could become a dweller in the land. The evidence of progress and adaptation to its environment on the part of the root is, in fact, so striking and conclusive, that we might take it as a text for a sermon on evolution were such necessary. I have been strongly tempted to occupy some more time with reference to the interesting phenomena shown by roots which cling to trees and walls, &c., or which rob other plants of food-materials; and had time allowed, I would have liked to say a few words about some other adaptations, such as those by means of which roots become pulled up taut in the soil. However, these and other matters cannot be even mentioned, and, indeed, each one deserves a lecture to itself.

FOCAL LINES

WHEN a pencil of light proceeding from a luminous point is incident upon a prism, the rays after refraction do not as a rule diverge from a point, but from two short lines at right angles to each other at some distance apart depending on the angle of incidence of the pencil. These lines are known as the focal lines of the pencil. If the edge of the prism be vertical and the axis of the pencil lie in a horizontal plane, the focal lines are respectively horizontal and vertical. The position of the horizontal line is independent of the angle of incidence of the pencil, its distance from the prism being the same as that of the luminous point, or with the notation of Parkinson's "Optics" (p. 88)—

$$v_2 = u.$$

The distance from the prism of the vertical focal line is, on the other hand, dependent on the angle of incidence, its position being given by the formula—

$$v_1 = \frac{\cos^2\phi' \cos^2\psi}{\cos^2\phi \cos^2\psi'}.u.$$

The image of an object viewed through the prism will appear between the two focal lines, and will be formed by the circles of least confusion. The two focal lines will coincide in position, and they, and the circles of least confusion, will consequently become points if $\phi = \phi'$, that is, if the prism be placed in the position of minimum deviation.

All these phenomena of refraction by a prism, which are of great importance to the spectroscope, may be verified in a very striking manner by using as an object a piece of wire gauze, placed so that one set of wires is horizontal and the other vertical, and illuminated by a sodium flame placed behind it. If the light pass directly from the gauze to the prism, the focal lines are of course virtual, but they may be easily viewed and their positions identified by means of a telescope which will focus an object at a short distance. For one position of the eye-piece of the telescope the vertical wires are seen distinctly while no horizontal wires are seen; whereas for another position the horizontal wires may be focused, but then the vertical ones are no longer visible unless the prism is in the position of minimum deviation. Between these two positions of the eye-piece is a third, for which a blurred image of the gauze is seen corresponding to the circles of least confusion. The positions of the lines may be determined by ascertaining where an object must be placed, when the prism is removed, so as to be in focus in the telescope for the two positions of the eye-piece corresponding to the two focal lines respectively.

The experiment is, however, much more striking if the focal lines be made real by interposing between the gauze and the prism a convex lens of somewhat long focal length. The vertical and horizontal images may then be viewed by means of an ordinary watchmaker's glass, or, better still, by a telescope eye-piece mounted behind a second gauze with its wires set at 45° to the horizon. With this arrangement the images corresponding to the two focal lines can be seen very clearly, and their distances from the prism accurately measured. It is very interesting to place the prism first in the position of minimum deviation, and focus the magnifier upon the image of the gauze, showing both horizontal and vertical wires clearly defined; then on gradually turning the prism the vertical lines disappear completely, leaving a set of horizontal bars across the uniform field, thus verifying the first formula cited above.

If however, the eye-piece be drawn back some way, a badly-defined image of the gauze can be obtained corresponding to the circles of least confusion, and, on withdrawing the eye-piece still further, the horizontal lines disappear entirely, while the vertical lines come out sharply defined as a set of vertical bars across a uniform field. As the experiment was arranged here, with a prism of about 9° and the horizontal focal line about two feet from the prism, the distance between the two images was fully six inches when the prism was turned through an angle of about 15° from the position of minimum deviation.

The properties of the focal lines formed by a pencil incident