It snows in the Australian Alps very much in the winter, and the prevailing westerly winter winds pile up masses of wind-blown snow just below the high ridges on their eastern or lee side. These masses of snow never disappear altogether in summer, and we find eternal snow in the Australian Alps at an elevation of 6500 feet.

The excessively clear and bright Australian atmosphere affords no obstacle to the nocturnal irradiation of the day's heat, and so it freezes very frequently there at night, even in midsummer, down to 5000 feet. I experienced severe frosts on Mount Kosciusco in January 1885 —January corresponds to our July—whilst it was intensely hot in the adjacent lowlands.

From these statements it is evident that we have in the Australian Alps a formidable mountain-range, which, although not glaciated now, would bear glaciers if the climate were slightly colder and more humid.

It seemed particularly surprising, therefore, that the older authors on Australian glaciation had given a verdict without examining the Alps. If no glacier traces were found in the lowlands, they yet might be found in the Alps; and if glacier traces were found in the lowlands, how much more extensive must they be in the mountains. Up the mountains I accordingly went to look for them. I undertook two expeditions. In 1885 I visited the Kosciusco group and ascended Mueller's Peak and Mount Townsend, and this year I explored the Bogong range and ascended the highest mountain in Victoria, Mount Bogong.

The Governments and learned Societies of New South Wales and Victoria greatly assisted me in my work by pecuniary aid and in other ways, and I am glad here to find an opportunity of expressing my gratitude for the great—I might say splendid—liberality with which the Australians have aided me. On my second journey I was accompanied by Mr. James Stirling, District Surveyor of Omeo, whose well-known essays on Australian glaciation have closely connected his name with the subject I had in view.

I was favoured with fine weather on both occasions, and on both occasions travelled through country never previously explored by any one with practical mountaineering experience. North of Mount Bogong I travelled for three days through country hitherto unknown. I found glacier traces on both occasions in great abundance, and in a sufficient state of preservation to be recognised as such without the shadow of a doubt. On the sides of the valleys of the tributaries to the Snowy River, which drains the eastern slopes of the Kosciusco plateau, I found abundant *roches moutonnées* at levels over 5800 feet, and high above the bottoms of the valleys. Also in some parts of the table-land itself such were found. With a little Alpine experience it is not difficult to discriminate between such ice-worn rocks and the ordinary bosses of weathered granite. These rocks are particularly well-defined in the Wilkinson Valley, the upper part of which is situated between Mount Townsend and Mueller's Peak. The bottom of the upper part of this valley is a broad and flat plain 6260 feet above sea-level. The hill-sides which surround it are everywhere worn down by glacial action up to about 800 feet above the valley bottom. The upper limit of ice-action is clearly marked, as in many valleys of the European Alps, and the thickness of the prehistoric ice stream thereby clearly indicated.

On the southern slopes of Mount Bogong, and also on the spurs of the northern flank of the mountain, basaltic erratics were found, which rocks could hardly have been transported to that locality without ice-action. In the valley of Mountain Creek, to the north of Mount Bogong, we discovered a large and well-preserved terminal moraine at an elevation of about 2800 feet, and some traces of others further down the valley.

The large moraine was carefully studied by Mr. Stirling and myself. Rocks of various kinds are scattered irregularly in it. It extends from one side of the broad valley to the other, and is cut through near the centre by the Mountain Creek. On the steep slopes towards the stream its composition of rocks brought down by an ice-stream can be easily recognised.

These two expeditions to the Australian Alps convinced me that at one time these mountains were glaciated, and the discovery of the moraine in Mountain Creek Valley, together with Stirling's (*l.c.*) elaborate researches in the Livingstone Valley, prove that the ice-streams of the Glacial period must have descended to pretty low levels. Down to 2000 feet glacial traces have been found in various parts of the Alps, and also in the Lofty Mountains near Adelaide. It is assumed by C. Wilkinson and other leading Australian geologists that a pluviatile period existed in the Miocene period, and it is obvious that such a period would probably be isochronous with the glaciation at high levels.

It is difficult to say whether the Australian and New Zealand glaciation was simultaneous, but that also appears probable. The better preservation of striæ, &c., in New Zealand is doubtless due to the greater hardness and resisting power to meteorological influences, of the ice-worn rocks in New Zealand than in the Australian Alps, where rapidly weathering granite is prevalent.

Whether this glaciation of Australasia was simultaneous with the last glaciation of Europe, or whether it was in time situated between the last glaciation and the last but one of the northern hemisphere, is not easy to decide. It appears nearly certain that it was *not later* than the last European Glacial period, and, as far as my opinion of the appearance of the traces it left behind goes, it was *earlier*. It may be hoped that future researches will show in a decisive manner whether it was simultaneous or earlier. If we do not consider merely local circumstances of sufficient effect to produce such a great change of climate as to cause so extensive a glaciation, we may, by arriving at the decision of the time of the Glacial period in Australia, also ascertain whether Glacial periods in the southern and northern hemispheres are *simultaneous or alternating*, which would give a clue to the difficult problem before us.

The necessary researches will doubtless be carried on with vigour by Australian men of science; and we may hope that their sagacity and perseverance may lead to the solution of the question, What is the cause of Glacial periods?

R. VON LENDENFELD

ROOTS[1]

It is a fact which has become more and more evident to the practical cultivator that the results of his efforts manifest themselves on the whole in a sort of compromise between the plant and its environment: I mean that although he sees more or less distinctly what his plant should be—according to a certain standard, however—it is but rarely, if ever, that the plant cultivated perfectly fulfils in every respect what is demanded of it. Of late years this has of course forced itself more prominently before the observer, because the facts and phenomena constituting what is termed variation have been so much more definitely described, and the questions arising out of them so much more clearly formulated.

Two points can be asserted without fear of contradiction: first, the plant itself is a variable organism; and, secondly, its environment varies. Now within limits which are somewhat wide, when closely examined, the experience of man leads him to neglect the variations occurring around him, and so no one quarrels with the statement that two individual geraniums belong to the same variety, or two oak trees to the same species,

[1] See NATURE, vol. xxxi. p. 183. A lecture by H. Marshall Ward, M.A., F.L.S., Fellow of Christ's College, Cambridge; Professor of Botany in the School of Forestry, Royal Indian College, Cooper's Hill.

although an accurate description of each of the two geraniums or of the two oaks might require very different wording.

It has also become more and more evident that although we cannot ascribe all variations to their causes —very often, indeed, we cannot even suggest causes for them—there are nevertheless numerous deviations from the normal, so to speak, exhibited by plants which can be distinctly referred to certain deviations from the normal on the part of their environment.

To illustrate this we may take the case of two plants of that very common weed, the Shepherd's Purse, growing at different ends of the same small plot of ground: the soil is sandy, and so much alike all over as to be regarded as the same everywhere, nevertheless the plant at one end is large, more than a foot high, and luxuriant, with many leaves and flowers, and eventually produces numerous seeds, whereas that at the other end is small, less than 4 inches high, and bears but a few stunted leaves and three or four poor flowers and fruits. The cause of the difference is found to be the different supply of water in the two cases, and if any one doubts that this may be so, let him try the experiment of growing two or more specimens of this weed in pots: the pots to be new, filled with soil which has been thoroughly mixed, and all the pots exposed to the same conditions—*i.e.* practically the same—except that those of one series are watered sufficiently often, and those of the other only just sufficient to keep the plant actually living. The experiment is easy and conclusive with such a weed as the above. Now, it is just such experiments as that above described—some of them equally simple, others less so—that the physiologist devotes much of his attention to, and in just such a manner has been gathered together a nucleus of information around which more knowledge can be grouped.

I may make these points clearer by again quoting an illustration, and, not to confuse or mislead you by going too far afield, I will keep to the same line of investigation, partly because it is quite as simple and conclusive as any other of many that might be selected, and partly because it may be possible to set before you some facts which are interesting or even new to you.

It has been found that in some cases where two plants are growing in the same soil and under the same conditions as above, but where one plant receives less water than the other, that the dwarfed drier plant is more hairy than the larger and luxuriantly growing plant, which has been well watered. On looking more closely into this matter it turns out that the extra hairiness is (in some cases at any rate) simply due to the fact that the hairs are closer together, because the little cells on the outer parts of the plant which grow out into hairs do not increase so much in length and superficial extent as those on the well-watered plant, and thus the hairs stand thicker together on the same superficial area of the organ —of a leaf, for instance. In other cases, however, the hairs are really increased in numbers and length—the plant is absolutely more hairy. It will be noticed that details concerning growth and turgidity, and of the influence of various minerals, and so on, are not under consideration here. I am not asserting that all cases of hairiness in plants are to be ascribed to this cause; but it does occur, as stated, and the point is a curious one in view of the fact that very many plants which grow in sandy dry soils are conspicuously hairy, whereas allied species growing in or near water, or even only in moister situations, are devoid of conspicuous hairs, or even quite smooth.

The above peculiarity is not confined to leaves and stems, moreover, for experiments with roots have shown that the root-hairs, which are so important in collecting moisture, &c., from the soil, can be made to appear in enormous numbers when the root is kept in a soil which is very open and only slightly moist, whereas none or very few are developed on the same roots growing in water: this again is in accordance generally with the fact that the roots of land-plants growing in light soils develop innumerable root-hairs, whereas those of water-plants do not thus increase their surface and points of attachment. I cannot here go into all the interesting facts known about these hairs, but it will be sufficient if you bear in mind the main points just mentioned.

Let us now vary the experiments a little. It is obvious that we might suppose any number of differences in the amount of water given to the plants used in the experiments described above; but it would be found, as matter of fact, that however little be the quantity of water given to the soil in which the dwarfed plant is, compared with that put into the soil in which the luxuriant plant grows, the actual weight of water will nevertheless have to be considerable, taking the whole life of the plant into consideration—there will be more used than you probably know, moreover, because the soil itself will no doubt condense and absorb some from the atmosphere during the night. There is a minimum of water absolutely necessary, and if the plant does not obtain this it will die. Its death will be ushered in by drooping and withering of the leaves, stem, and roots, and this condition, in which the functions of the plant are interfered with beyond a certain point, passes into a condition of disease.

Now take another case. We might so arrange the experiment that we poured and continued to pour too much water into the soil. Here again it would be found that a condition of disease eventually sets in—*i.e.* a condition in which the functions of the plant are again interfered with beyond a certain point. The symptoms and progress of the disease will be very different in the latter case, however, from those in the former. It may also be mentioned that in neither experiment is death inevitable if the disturbing cause is removed soon enough—*i.e.* if sufficient water be added in the first case before the cells have ceased to be able to take it up, or if the previous conditions of the soil are restored soon enough in the case of the over-watered plant.

Here we come to a matter which is less simple than may appear at first sight. You will note that the problem in the latter case is to restore the previous conditions of the roots and soil soon enough; I put it thus, because the conditions of the roots and soil may soon be very profoundly altered by the over-watering.

To understand this, it is necessary to become a little more fully acquainted with the condition of affairs in what may be called the normal case, where the soil is light and open, and plenty of water but not too much is at the disposal of the roots. Such a soil will consist of innumerable fine particles, of different shapes, sizes, and composition. No doubt there will be grains of quartz, particles of broken up vegetable matter, and little rugged bits of stones containing various minerals; each of these tiny fragments will be covered with a thin layer of water, and you would probably be greatly surprised if I were to go into the proofs showing how extremely tenacious of its water-blanket each particle is. It may be enough for our present purpose if you accept the fact that it requires enormous force to deprive the particles of the last traces of their water-layers; they will give off some—or in some cases even a good deal—rather easily, and in fact when the layers become of a certain thickness no more water can attach itself to the particles, but it falls away and the soil remains saturated, as we say.

Now these particles of soil, each enveloped in its water-blanket, are not in close contact; there are spaces between them, and these interspaces influence the quantity of water which can be held back by the soil.

Let us suppose such a soil perfectly dry; the particles above referred to being irregular in shape and size, and only roughly in contact at various points, the interspaces will be filled with air. If water be then added in some quantity, each of the particles becomes clothed with a layer of water, and some of the air is driven out, though bubbles of air will still exist in the larger interspaces.

A third case is conceivable—so much water might be supposed to find its way in, that no air remained in the interspaces between the particles of soil. Now it is true that such a state of affairs is not readily brought about in a normal soil; but I may indicate how the result is occasionally attained to a great extent. Suppose that a layer of clay or other impenetrable subsoil lies beneath the soil in question; then if water oozes into the soil in larger quantities than can be got rid of in the time, it is possible for nearly all the air to be displaced. Of course the object of good drainage is to prevent this; and it is often overlooked that drainage from below has the effect of drawing in air as well as of running off superfluous water—air is driven into the spaces as the water leaves them.

In speaking of the "bubbles of air" entangled in the interspaces between the particles of soil, each with its water-blanket, I have overlooked some details as to what the bubbles really are. As a matter of fact they will not remain of the same composition as ordinary air, and may soon differ considerably; besides the vapour of water, they may contain gases in quite different proportions from those in the air outside. In the type case, however, there will be some oxygen present in the bubbles.

It is not intended here to go very fully into a description of the structure of the roots of land-plants; enough if you are reminded how the smaller ramifications of a root are found to be more numerous and thinner as we approach the periphery of the mass of earth which they traverse. From the youngest rootlets are produced the root-hairs, in enormous quantities, new ones arising forwards—*i.e.* near the tip of the rootlet—as the rootlet grows on, and those behind dying off after fulfilling their functions. These functions are chiefly to apply themselves in the closest manner to the surfaces of the particles of soil, and in this way to place the water which they contain in direct continuity with the water which clings with such enormous force to the surfaces of the particles. Hence this water can pass from the soil to the plant, and anything dissolved in the water can also pass into the root-hair and thus up into the plant.

I am not going to dwell on how the root-hairs themselves aid in dissolving mineral substances—corroding the surfaces of the particles of soil they cling to—nor shall I trouble you with the details of what substances will be dissolved in the water; for, of course, you will see that anything soluble will pass into solution and may be carried into the plant.

The chief point to be insisted on just now is that this water in the soil will contain among other substances oxygen dissolved in it from the air-bubbles referred to above, and that this dissolved oxygen will pass into the root-hairs in solution together with the minerals and any other substances. This oxygen, moreover, is absolutely indispensable for the life of the root-hairs; it can be easily shown that if the supply of oxygen is stopped, or even diminished to any considerable extent, the roots begin to die, because the root-hairs cease to act.

Let us look a little more closely into this point. Each root-hair is a tiny cell containing living protoplasm and certain other substances, all inclosed in a thin, elastic, porous membrane. Now it has been abundantly proved that if such a cell is deprived of oxygen, its protoplasm becomes dormant for a time, and slowly breaks up, as it were; subsequently it becomes decomposed into other and simpler materials. A sort of internal combustion and fermentation take place, and these processes result in the formation and liberation of bodies like carbon-dioxide, alcohol, acetic acid, and other acid matters—substances in the main not only incapable of supporting the life of the root-hairs but actually destructive of it.

Evidently, then, if we deprive all the root-hairs of oxygen, they will eventually die. Their death will entail that of the rootlets and roots to which they belong, and this for two obvious reasons—first, it is the root-hairs and the root-hairs alone which can absorb the necessary water and substances in solution from the soil to supply such a plant as we are concerned with; and, secondly, the noxious products resulting from their death accumulate in the soil and diffuse into the root, and so hasten similar decompositions in what were hitherto healthy cells.

It must not be supposed that these disastrous consequences of the deprivation of oxygen always follow imme diately. Not only are the roots of some trees, for instance, able to withstand ill-treatment longer than others, but, obviously, the kind and degree of ill-treatment may affect the problem of how long the plant shall survive. The number of rootlets and root-hairs, and the spread of the roots and other factors, will obviously affect the matter.

Suppose the following case as an example. A young tree is growing and flourishing in an open, good soil, and, for some reason or other, more soil is heaped about the roots until the depth is increased considerably: the deeper situation has placed obstacles in the way of the roots obtaining oxygen so readily as before. Not only are the roots further from the atmosphere, but the water carried down has to percolate through more soil, and may part with much of its oxygen (or even all) on the way: of course the nature of the soil, the presence of organic matters, and other circumstances decide this. It is not at all difficult to conceive of such a case where the supply of oxygen to the roots is thus diminished so far that the activity of the root-hairs as a whole is simply lowered, but not destroyed,—a stage or two further and they might become dormant, and their protoplasm undergo intra-molecular respiration for a time, and break up. It is clear that the diminished activity of the roots will affect the supply of water (and the substances dissolved in it) to the leaves: this will obviously react on the thickness of the annual rings, and this again on future supplies—since the water passes up the alburnum or young outer layers of woody tissue. Moreover, a diminution of supplies from the leaves means less substance and power for replacing the root-hairs, and so on. In this way it may require some time to kill the tree, and all kinds of complications may arise meanwhile. This case is probably by no means uncommon.

A more extreme case is where the soil becomes damp and clogged with excessive moisture: not only does no oxygen reach the roots, but noxious gases accumulate in solution in the soil, and will hurry matters by poisoning cells which might otherwise live a longer life of usefulness. It is extremely probable that such gases find their way into higher parts of the plant in the air-bubbles known to exist and to undergo alterations of pressure in the vessels of the wood: this being so, they would slowly retard the action of other living cells, and so affect the upper parts of the plant even more rapidly than would otherwise be the case. Damp soil may thus do injury according to its depth and nature; but it need not necessarily be deep to be injurious if much oxygen-consuming substance is present. I have seen excellent soil converted into damp, stinking, deadly stuff from the action and accumulation of the larvæ of cockchafers: these "grubs" may, it is true, accelerate the devastation caused by the consumption of oxygen and the accumulation of poisonous waste matters in the soil by directly cutting off portions of the roots themselves, but the accumulation of oxygen-consuming substance, and the cutting off of supplies to the root-hairs evidently plays a chief part in the destruction.

There is another matter with regard to damp soils that cannot be left out of account. I have already told you that roots which are developed in water or in very damp sandy soil—and which are perfectly healthy—have few or no root-hairs formed on their surfaces; whereas it may be readily shown that the roots of the same plant growing in a well-aërated open soil, which is scarcely moist to all appearance, will be densely covered with a close-set pile of hairs. Indeed it is by means of the millions of root-hairs on its rootlets that a sunflower or a bean, for instance, obtains the enormous quantities of water necessary for its needs from soil which, to our rough perception, seems to be dry.

I cannot here go into all the proofs that such a soil is by no means so dry as it looks; but will simply remind you of what was said above as to the enormous force with which the minute particles of rock, &c., which form "soil" retain their hold on the thin films of water which constitute what have been termed their water-blankets. This is certain, that a healthy well-rooted plant can take up water from a soil which is to all appearance air-dry; whereas a plant which has not yet had time to develop its root-hairs in sufficient numbers to take these firmly adherent water-films, from numerous particles of soil, would droop and wither.

Of course it must be borne in mind that we are speaking of land-plants such as we commonly meet with on ordinary dry land: in the case of plants which flourish in bogs or in water there are corresponding differences in the structures of their roots agreeing with the differences of environment. Even such plants need air at their roots, and an excellent illustration of this is is afforded by some willows. Our common osier and other willows grow, as you are aware, in low-lying damp and even boggy places, often flooded: now, it has been found that, if young willows are planted too deep in the soil, they very soon send out new roots—adventitious roots they are often called—close to the surface of the soil, and these roots soon do all the work. There is no doubt that this power enables these willows to live in places that would be fatal to them otherwise; and the same is true of some other plants.

Enough has now been said to show you how necessary it is that some care should be exercised in watering plants, or in exposing them to conditions different from those to which they are accustomed; and, it need scarcely be added, apparently mysterious diseases may sometimes be explained when it is shown that such precautions have been neglected. Any one can quote instances of plants which will grow in some soils and not in others, but no very satisfactory reason is afforded by simply saying that the one soil is suitable and the other not: however, all I have attempted to show you is that some soils are not suitable for some plants because the plants in question need more air at the roots than these particular soils can afford them under the circumstances.

Many plants flourish in an open soil with plenty of sand in it, but will not grow in a stiff wet soil. This is not necessarily because the heavier soil does not contain the right food-materials, but because its particles are so small, so closely packed, and so retentive of moisture, that the root-hairs do not obtain sufficient oxygen: moreover, the very damp state of the soil does not favour the development of the numerous root-hairs necessary, as we have seen. Nor is this all,—though I cannot here enter at length into this point,—root-hairs and roots cannot grow or act unless the temperature is favourable, and we have plenty of evidence to show that a close wet soil may be too cold for the roots at a time when an open drier soil (exposed to similar conditions as regards sunshine, &c.) would be of a temperature favourable to their growth. Many a pot-plant receives an extra over-dose of water because it is drooping from the roots being too cold to act properly. The opening up of stiffer soils by means of the spade or plough, or by the addition of other kinds of soil, such as sand, burnt lime, &c., or by means of drainage of various kinds, is thus to be regarded as a means of letting in air and therefore oxygen to the roots. "Sweetening the soil" is an expression one hears used by planters and others: this is often no doubt their way of expressing the fact that the air thus let in does so much to turn the noxious substances which have accumulated into other substances which the root-hairs of the plant can take up with profit. The exposure of certain soils to sharp winter frosts in part benefits the plants subsequently grown in it, because air can make its way into the cracks produced as the particles crumble: there are other advantages also due to the "weathering" of soils, of course, as also to the addition of lime, &c., but I am purposely abstaining from referring to points concerning the nutrition of plants as generally understood.

Let me shortly call your attention to a few other practical applications of the knowledge briefly summed up above. It is well known that a good deal of experience has been brought to bear on the question of what trees are the best to plant in or near large towns: there are very many facts to be considered. It is not sufficient to find a tree which will accommodate itself to the possibilities of the annual rainfall, or a diminished supply of sunlight throughout the year, and so on; nor is the problem solved when a tree is found that will put up with traces of acid gases in the atmosphere, and, as may follow, the accumulation of acids in the soil, and consequent alterations in its chemical composition. In many cases trees have been found to die as they grew older because the pavement or asphalt over their spreading root-system prevented proper aëration and a proper supply of aërated water to their root-hairs: imagine the effect of a few days' hot summer sunshine on roots just beneath the pavement of an exposed street! It is true the cover may prevent rapid evaporation, but it also shelters the soil from the well-aërated rain-drops; moreover, such sheltered roots will at certain seasons grow up to the surface of the soil and in contact with the lower surface of the pavement. Then there is the question of drainage. If the water which does find its way in slowly accumulates and becomes stagnant, the results are as disastrous or even more so; yet it is obviously a difficult matter so to arrange things that the accumulated surplus water of certain seasons shall pass away below, acting like a suction-pump and drawing in air after it, and still fulfil the other requirements hinted at above. I leave out the question of exhaustion of the soil—the dead leaves, &c., being carefully removed. Can we wonder that there are so few trees to choose from that will stand such treatment? The fact that there are some only accords with what has been already stated—that plants vary in their requirements and powers; and no one doubts that the variations have been influenced by variations in the environment.

We have now seen to a certain extent how variations of a particular kind may affect a plant. The plant responds to a certain extent—it is, as some people say, "plastic"—but if the limits are reached and slightly overstepped, the variations on the part of the plant become dangerous to its existence, and the plant becomes diseased and may die.

Not to dwell upon hypothetical matters, I will content myself with saying, in conclusion, suppose a variety of a given plant grows in damp places and has roots which form few or no root-hairs, and suppose an individual of that plant to become transferred to a more open soil: I have shown you reasons for regarding it as probable that the latter individual might produce more root-hairs and thus adapt itself to the altered conditions. If such a case happened, it is by no means improbable, but the contrary, that other circumstances co-operating or adverse would decide certain problems of importance to the existence of that particular individual.

But the main object of this lecture has been to show you how very complex the conditions may be which bring about a "diseased" condition of the roots. It is no uncommon event to see a tree flourish for years and then slowly die off from "something at the roots": examination shows that the soil still contains the necessary foods, the water-supply is constant and good, the tree is exposed to no obvious adverse influences, and yet with steps so slow that they are scarcely noticeable, the tree begins to die off before its time. In some cases this is probably because the root-hairs are not receiving their proper supply of atmospheric oxygen, and this may be due to very slight changes in the *structure* (not the chemical composition) of the soil: a very slight diminution in the activity of the root-hairs may cause a diminution in the supply of water to the leaves at seasons when they require much, and this means lessening their supply of food-materials. If the leaves are placed on short commons, they cannot form wood, and so the next season's supply of nutritive solutions may be cut short; moreover, fewer root-hairs will be formed. No doubt differences will appear in different years or seasons; but if the tendency on the whole is in the above direction, the life of the tree is already limited—it may drag on for years as an object, which can scarcely be termed a tree however, but its doom is sealed.

The difficulty of placing one's hand on an exactly illustrative case is due to the fact that other causes are usually at work after a short time. I have purposely avoided any reference to the changes brought about in the chemical nature of a soil by the addition or cutting off of air, &c.; and for the same reason—to keep your attention directed to the root-hairs as living cells exposed to the influence of a definite environment—I have left out of account some questions of food-supply. These matters do not invalidate anything said above, but they do profoundly affect the problems of the diseases of plants, and especially those diseases which start from the roots.

ON THE PROPOSAL TO ESTABLISH A PERMANENT COLONIAL MUSEUM IN LONDON

THE proposal to continue the present Colonial and Indian Exhibition at South Kensington having met with a good deal of support, it is worth while to examine it on its merits; quite apart from the popular accessories of music, illuminations, &c., the continued existence of which depends upon altogether different considerations.

The first point for examination is whether such a permanent exhibition or museum would materially and usefully supplement or form a real addition to the existing public institutions of London, for upon the determination of this question the decision ought largely to depend.

On a general review of the vast collection of objects exhibited in the present Exhibition, they are seen to be mainly included under the four following categories:—

(1) Natural history objects, or specimens of the animal, vegetable, and mineral kingdoms of Nature.

(2) The raw products derived from them, and their economic applications.

(3) Art of every description, with which may be included objects bearing upon archæology and ethnology.

(4) Manufactures of all kinds.

(1) With reference to natural history, it can scarcely be a public desideratum to attempt to form a new museum of this kind when there exists, within a few hundred yards of the Exhibition, the finest collection in the world in the great national Museum of Natural History. There the animals, plants, fossils, and minerals not only of the British colonies, but of the whole known world, are exhibited with a fullness and in a manner that there could not be a possibility of in any way approaching.

(2) Then, as regards the economic uses of the vegetable kingdom at least—such as food-products, drugs, timbers, &c.—the nation possesses in the Museum of Kew Gardens a probably unrivalled public collection admirably exhibited. Many years of energy and a very large expenditure of time and money would fail to make up again such a collection as this has now become.

(3) Objects of art both ancient and modern form a very striking and important portion of the Exhibition. It is probable, however, that the best part of those which are not on loan have been sold or otherwise disposed of, and thus are not available for future exhibition. But with the South Kensington Museum at our doors, the initiation of a new art collection cannot be needed; whilst as for objects illustrative of ethnology and archæological specimens, they are, it is needless to say, magnificently displayed in the galleries of the old British Museum in Bloomsbury.

(4) There remains only the commercial products and manufactures of the colonies and India, and, so far as I am aware, there exists at present no general public collection of such articles. Here then, it appears to me, we have a reasonable basis for the formation of a permanent museum. A public collection of trade samples is a real want in London.

It appears, then, from the above observations, that no necessity exists for a new *general* museum of colonial and Indian productions, inasmuch as the public is already amply provided with other museums which illustrate fully nearly all the objects and articles proposed to be exhibited in the new one.

There is also good reason to think that the multiplication of museums is undesirable as well as unnecessary. We are not without experience of this, and the history of the late India Museum is quite to the point. The vast collections brought together by the Honourable East India Company were quite similar in kind to those it is now proposed to form, and illustrated very thoroughly the productions of India. But the Museum never attracted public interest or proved of much practical utility; many departments were neglected, the specimens badly conserved, and not available for consultation or study, and at last its condition having become somewhat of an official scandal, it was, six or seven years ago, broken up and dispersed. It bears strongly on the remarks above made that the collections had to be distributed among the very museums which I have there enumerated. No doubt additions of much value thus accrued to them; but there was also an immense mass of duplicate and damaged material, some of which at least was destroyed. After this experience it seems scarcely credible that a proposal to form again another general *Indian* Museum in London will be seriously entertained, whatever may be the case as regards the colonies. But in the latter, as in the former, it is almost certain that from similar causes a few years would witness the same history and a similar termination.

It is then, I believe, in a permanent museum of trade samples and of the commercial products of our colonies that a really useful outcome of the present Exhibition is to be sought. The precise scope and character of such a museum would of course require careful consideration; but there is a great and increasing want of some central emporium of a public character where authentic samples, accurately determined and labelled, can be readily inspected and examined by those interested in commercial pursuits. The collection might well be arranged geographically, and should be accompanied by maps, trade statistics, and other aids to inquiry. Under able management such a museum would be capable of rendering great service to the commerce of the Empire, and be the means of bringing into trade the numerous neglected products of the world. I may add, parenthetically, that it would also relieve the staffs of our chief scientific establishments of a good deal of work, involving often much sacrifice of time, which now falls upon them, though outside the scope of their duties.

The situation of such a museum should, however, be