ON ROOT HAIRS.

BY TH. JAMIESON, ABERDEEN, SCOTLAND.

During the past fifteen years, in the course of carrying out a very large number of experiments to ascertain the relative effects of different forms of manure, and also, which of the mineral chemical elements usually found in plants are essential, no point was more strikingly illustrated than the inability of the plant to grow in the absence of phosphorus, although all the other essentials of growth were fully supplied. In its absence, the turnip plant, for instance, reached the stage of forming only leaflets, while neighboring plants, treated in every respect in precisely the same manner, only that they were supplied with phosphorus in addition, developed large plants, yielding a crop of about 30 tons per acre. No laboratory or lecture room experiment could be more effective than the positive and negative results shown by two such plots, side by side, and these evidences have been abundantly repeated annually.

In following out an inquiry bearing on this remarkable action, a special microscopic examination of root hairs was suggested; special in respect of introducing various conditions of light and shade, even approaching darkness, as well, of course, as adjustments of the focus under various degrees of light. This is specially mentioned in order to indicate that the feature on root hairs about to be explained is such as might easily escape notice in an ordinary examination. An unlooked-for structure was thus detected, as a consequence of attention being so long concentrated on the tip of the hair and of gazing continually on the spot under cautious and slight alterations of both light and focus. It was seen that there was *a well-defined aperture*. The aperture in the first case of detection was so clearly defined, and moreover seemed so clearly continuous with the inner membrane or tube of the hair cell, that no doubt was felt that there was an aperture. Possibly it would not have been discerned had it not been on an unusual part of the hair, viz.: a little below the point, so that the point formed a kind of cap. As a rule, however, the aperture is at the point.

So necessary is it to examine the root hair under varying conditions of light and focus, and also to travel along the inner lining of the tube with the eye till it reaches the point where the aperture ought to be, and so frequently is the aperture turned away from the point of view, that one familiar with the process can easily understand how any one not so familiar might rise from the examination and feel satisfied that the hair is, indeed, a a closed tube. Only persistence to continue, till the inexperienced observer falls upon a suitably placed hair, is followed by success.

After having observed so satisfactorily the first aperture, much time was spent during three years in examining the hairs of a large number of plants, and although from the state of the plant roots, and the condition and position of the hair, the aperture has frequently not been detected at the first examination, yet by another selection and persistent examination the aperture has been found without exception in the case of every plant examined.

On examination at this stage of the writings of the more eminent botanists on the subject, it was found that in few of these treatises is the detailed form of the hair gone into with sufficient minuteness.

The works of De Bary, Duchartre, Olivier, Gasparina, Van Lieghem, Sachs, Vines have been referred to.

The essential and accepted character given in all these works is: a complete and closed cell, thread-like in form and broadened at the base, where it is continuous with, and forms part of, the epidermis.

The more recent works by Schwartz, Zacharias and others dealing more particularly with root hairs have been examined, but the idea of an aperture does not seem to have occurred to them, and the negative evidence, of course, is not of any significance.

Referring now to the function of hairs as bearing on an aperture. None of the writers on the minute structure of hairs departs from the idea that the hairs are closed cells, or, as Sachs describes them, exceedingly delicate walled narrow tubes.

By accepting this view a difficulty arises. It has hitherto been found necessary to advance some explanation, for the well-known fact that the insoluble matter, such as phosphates, is assimilable by plants. Sachs says in explanation that these insoluble matters are without doubt dissolved in the thin layers of water which surround the particles of soil, basing this inference on the fact that water running off from the drained pipes of tilled soil contains these substances; but he infers further, that "since the nutritive materials clinging to the particles of soil are not soluble, or but slightly so in water, the roots must themselves effect the solution." This seems to be a kind of forced conclusion, *i. e.*, as the insoluble matter does get in, the particles *must* be dissolved, and, he asserts, without, however, giving grounds for it, that this solution is accomplished by means of the extremely thin membrane of the root hair being permeated with an acid fluid. Now, it is obvious that, it being once accepted that the root hair is a closed tube, and that side by side with this acceptance is placed the well-known fact that plants make use of insoluble matter, it becomes a necessity to assume, and it appears little more than an assumption, that the plants obtain their solids by the action of an acid. The usual statement is, not that the plant roots make use of an acid, but that they must make use of an acid, thus indicating that there was no other way of getting over the difficulty.

Van Tieghem also says that the roots set free an acid liquid which bathe their surface. He, however, undermines that statement by summarizing the functions of the root as a threefold action on the soil:

First—On the gases, by absorbing oxygen and disengaging carbonic acid.

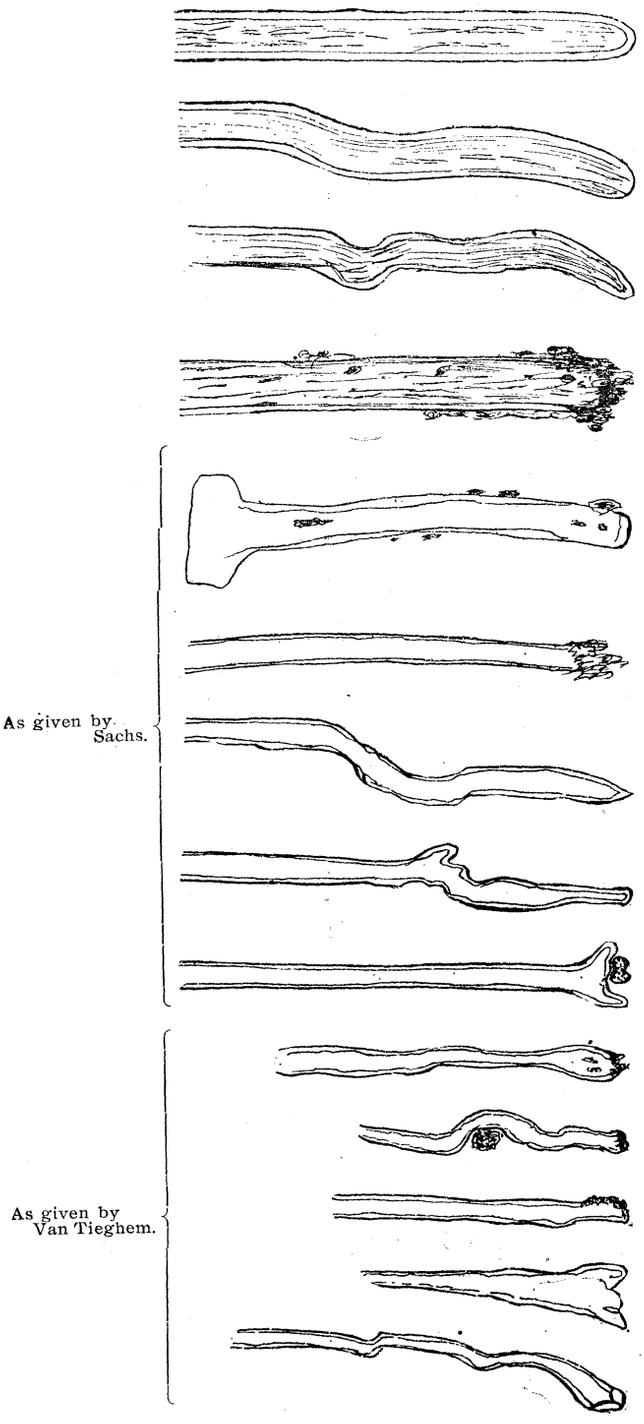
Second—On the water and dissolved matter, by absorbing them.

Third—On the solids, by dissolving them.

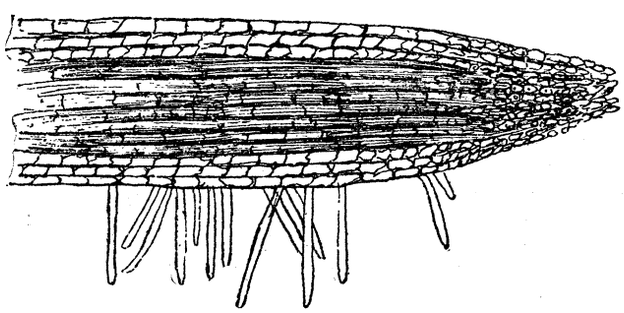
Now, it is evident that if the root acts so as to disengage carbonic acid, that acid alone is sufficient to account for the reddening of the litmus; and this circumstance takes away the support that such acid reaction might seem to give to the assumption that the plant forms an acid to dissolve the mineral food, unless, indeed, the dissolving acid be simply carbonic acid, in which case it would be uncertain whether the acid is there to dissolve insoluble matter, or is there as a simple product of decomposition. Vines asserts, however, that the reddening is permanent, and therefore is not due to carbonic acid.

Considering the slight evidence thus provided by Sachs and Van Tieghem, and that no observers seem to have found any special acid in the root, but simply acidity that may be accounted for by decomposition of the plant, or of organic matter in the soil, the dissolving action of the root hair seems to be little more than an assumption rendered necessary as an explanation of the well-known fact that insoluble matter is assimilated by the plant.

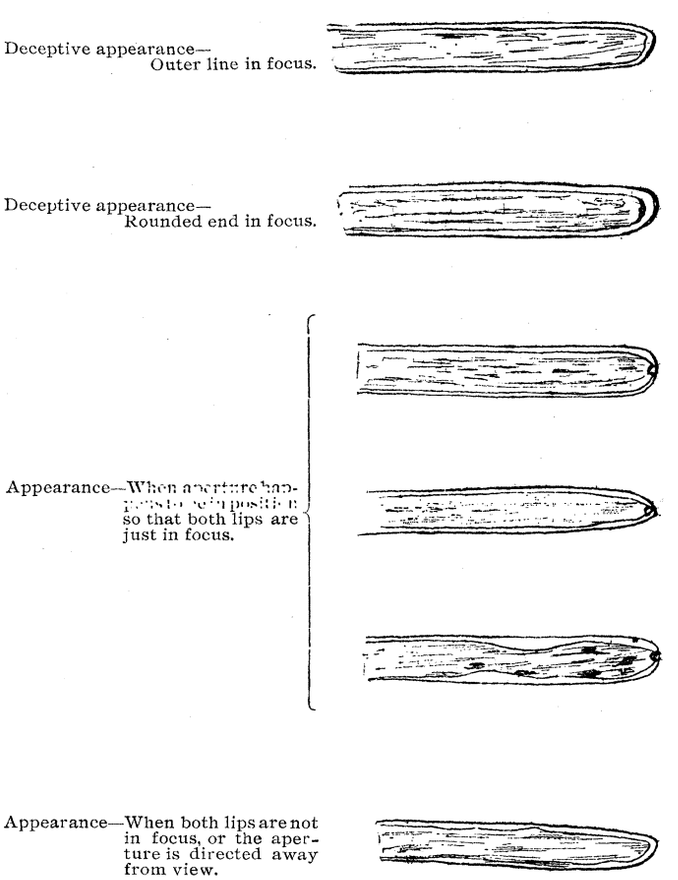
A difficulty in accepting the passage of solid particles by an aperture may seem to be presented by the consideration that, if solid particles enter the hair tip by an



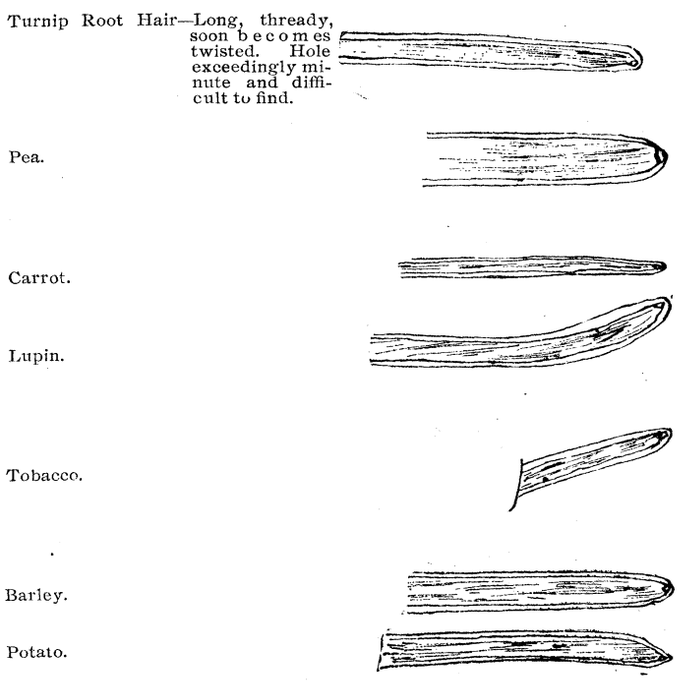
USUAL ILLUSTRATIONS OF ROOT HAIRS.



TIP OF OAT ROOTLET WITH ROOT HAIRS (much magnified.)



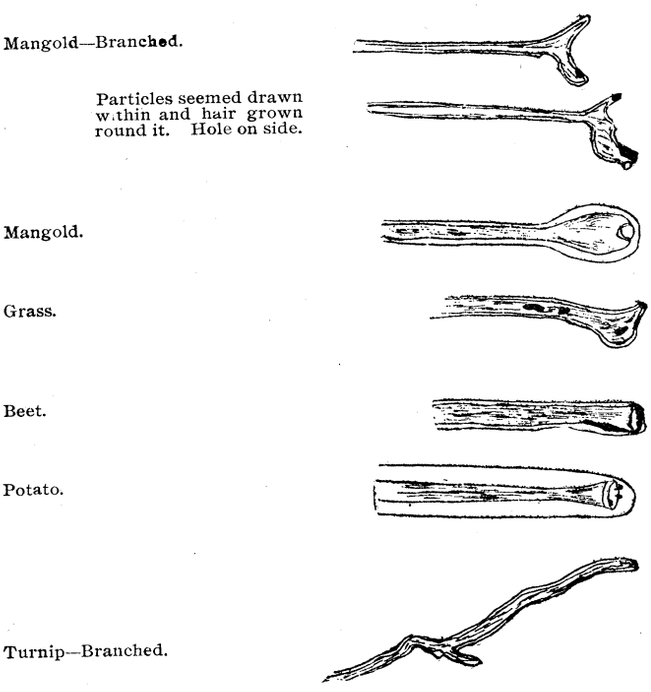
OAT HAIRS MORE MAGNIFIED.



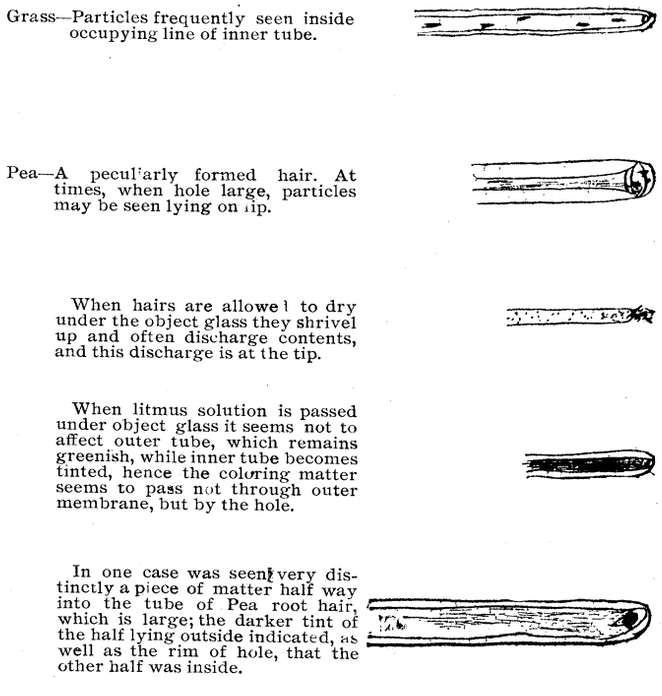
USUAL FORMS OF HAIRS.

aperture, they must either be decomposed inside the cell, or there must also be an aperture at the lower end, or that the particles should be forced out (as is done by the amœba). There may, indeed, be such a basal aperture which it would be difficult or impossible to distinguish. But close examination of the base of the root hairs indicates that, although they may originate in an epidermal cell, the internal part of the hair seems to communicate no real difficulty here, for it is known that decomposition takes place within the plant, and it may as well be done in a hair cell as any other cell.

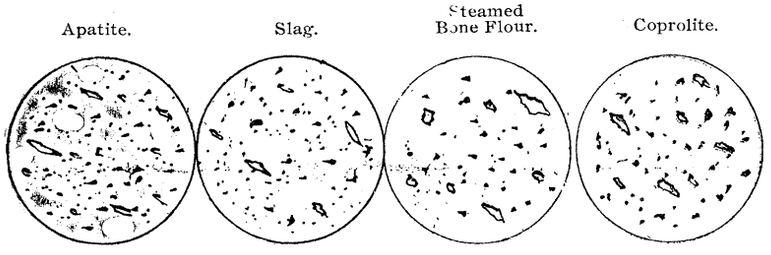
Having now considered the literature on the subject, observations made on the aperture may be returned to. That there is a definite formation of an aperture with lips, I have satisfied myself in regard to a large number of root hairs, illustrations of which are given here, and it will be



UNUSUAL FORMS OF ROOT HAIRS. (Rarely occurring in the above plants.)



ENTRANCE OF PARTICLES INTO APERTURE.



	Actual Number in Field.				Number Per Cent.			
	Minute.	Small.	Medium.	Large.	Minute.	Small.	Medium.	Large.
Apatite	43	17	3	43	65	25	4	6
Slag	13	21	4	3	32	50	10	8
S. B. flour	110	15	3	2	86	11	2	1
Coprolite	56	35	8	4	56	34	7	3

STATE OF DIVISION OF MANURES EFFECTIVE ON PLANTS. (Apative—crystalline—only slightly so.) Showing that in these manures there are particles so minute as to be able to pass into aperture of root hairs.

with the deeper tissue, or possibly with the vascular tissue. Thus in examining the root hair of a carrot, the faint bluish-grey appearance of the central tube was seen to be continuous with the deeper tissue, though whether entering into a vessel, or simply passing between the cells, could not be distinguished. This relation of the hair with the deeper tissue is supported by the origin of hairs as described by Schwartz and Duchartre. But there is seen that they vary not a little, both in shape and position, being usually a minute circular hole at the extreme, and more or less tapered, end of the inner tube, with, of course, a correspondingly larger rim in the outer tube; but sometimes the opening is transverse, sometimes not quite at the tip, or, rather, the tip seems half curved, making the aperture appear slightly at one side, and the tip to appear like a lip or knob.