

that the stem resembled a clavate brush, or cylindrical brush and in some cases approached a moniliform appearance. Where branches were formed they were short. The leaves varied in size from the normal to many which were almost filiform, and were scattered among the normal leaves from the commencement of leaf formation to the tip of the stem. In most of the plant showing the abnormal condition the large leaves were different as to margin also. The larger of these leaves, in many of the plants, were normal as to size and shape. Most of them were entire. The others on the same specimen were coarsely and sparsely serrate. The writer has also observed this same transformation in *Erigeron* of the Indiana Sand Dunes though less pronounced, and plants of this species also sent me from Illinois. A somewhat similar condition sometimes produced traumatically should not be confused with the above mentioned state which in some cases is due to a more or less diseased condition. One specimen was observed in which a healthy normal stem of *Erigeron* was attached at the base to an abnormal stem which was equally vigorous but with the otherwise changed appearance as above described. In some specimens fasciations in the form of extraordinary stem flattening was evident. Monstrosities in *Trillium* and other plants, in some instances decidedly change the appearance of the plant as described in this paper.

A NATURAL PROOF THAT THE ROOT TIP ALONE IS SENSITIVE TO THE GRAVITATIONAL STIMULUS, II.

F. M. ANDREWS, Indiana University.

In the Proceedings of the Indiana Academy of Science for 1905 the writer contributed a paper showing that the root-tip alone perceives the gravitation stimulus. This was ascertained not by means of the glass-cap experiment as was successfully performed by Czapek, but as a result of the accidental and central breaking of the scutellum and its adherence in a firm and solid mass to the root-tip. In addition the coats of the grain remained attached to the separated mass of tissue about the root-tip and formed therefore an enclosure so strong that the root-tip was unable to free itself. The root-tip thus covered by this firm mass extended 3 mm. back from the tip, which in my specimens reached to the center of the embryo. The mass weighed 15 mg. The region of gravitational perception was thus completely covered and when placed horizontally showed no response to gravity. The grains of corn had been soaked and planted vertically as regards their long axis in a mixture of sifted and properly moistened beech and maple saw-dust.

Since 1905 the writer has observed and studied five other exactly similar specimens of *Zea mays*, which were accidentally discovered and which carried masses of tissue about the root-tip as above described. The occurrence of such a covering, as mentioned here, is therefore com-

paratively rare. It is not to be mistaken for those instances in which at times a certain amount of tissue may adhere as small local masses, as sometimes occurs laterally on the root of *Zea mais*. These specimens were all, as above stated, from vertically planted grains of *Zea mais*, as regards their long axis. Of the many thousands of seedlings grown for other experiments the five specimens reported here were the only ones showing the peculiarly enclosed root-tips mentioned, and were therefore of accidental occurrence. All of these seedlings had been grown in sawdust.

Attempts were made with many soaked grains of *Zea mais*, as well as with a large number of grains that were just ready to germinate, to cut the scutellum and testa in such a manner as to produce the mass of tissue about the root-tip as above described. These experiments were unsuccessful and after many such experiments, further trials were abandoned entirely. The root in each case had curved somewhat so as to approach the back of the scutellum, but as in my first experiments even this curvature allowed the mass of tissue to be easily removed or replaced. These cap-like masses were quite firm and strong enough to prevent the root, during the time of experimentation, from breaking them. The root was not damaged by them in any way and, since each of these tissue masses only weighed from 14 to 18 mg., their weight was too small to be of influence as regards the points at issue here.

Experiments were also performed with glass tubes at the same time on other seedlings of *Zea mais*. These glass tubes were about 3 mm. long and weighed from 30 to 40 mg. which weight should not be exceeded. These tubes were closed at one end and each arm had a length of 1.5 mm. as in my former experiments and in those of Czapek. The difficulty of making these tubes properly is very great. They must fit the root in a suitable manner. Equally necessary is the great care that must be exercised so as to avoid injuring the roots. In order to get the small weight required, narrow thin walled glass tubing was properly heated and drawn out to the same internal diameter as the root so as to fit it exactly, but not too tightly. It should then be bent at right angles, care being taken to avoid flattening at the curve. The tubes should then be carefully sealed at one end without contracting the closed arm to a smaller diameter than the root and without allowing an undue accumulation of glass at the closed end. It is advisable to leave a small pore or opening near the closed end which, however, should be very narrow. The open end should be slightly rounded by heating so as to avoid cutting the root when adjustment is made. Imperfectly made glass-caps have been the cause of many failures by different investigators in this study or have led to incorrect conclusions. This is the reason for the failures of Wachtel and Richter. The writer has tried various substances for making the caps for the roots of *Zea mais*, but none of these have served the purpose so well as glass.

There is no possibility, as Nemeč seems to assume, that the geotropic perception might lie in the root-cap. It must lie in the apex of the root since certain roots do not possess a root-cap. Even in those roots which possess a root-cap for a time, this is dispensed with later, and therefore

cannot be the region of gravitational perception. Where such a temporary root-cap is removed at first, the root perceives the gravitational stimulus just the same, so the root-cap in this case perceives no stimulus. The root-cap can also be removed mechanically and the root perceives the geotropic stimulus just the same. The same holds true of roots which normally possess a permanent root-cap, for in some cases such permanent root-caps may be removed by proper care, without great injury to the root tip. Nevertheless, here also the root-apex perceives the geotropic stimulus and responds in the normal way. The experiments of Piccard do not prove the points under consideration here and his investigations are open to question. In addition, the idea that the cotyledon apex is instrumental in geotropic perception in some of the Gramineae needs further study.

The masses of tissue above mentioned could be removed from the roots without damage if care was exercised. The root-tip then perceived the gravitational stimulus in the usual way and with normal speed and conduction. But as long as the mass of tissue remained on the root no response to gravity was possible. The roots with these masses of tissue were subjected to the same experiments described in my former paper on this subject and such as Czapek carried out with glass-caps. The rate of growth in the roots encased by these masses of tissue, as well as those roots that were enclosed in the glass-caps, was nearly as rapid as in roots of the controls which were entirely free. The danger of injury that the glass-cap method often occasions was eliminated by the masses of tissue which in some cases were present. Although these masses of tissue were of accidental occurrence, they nevertheless furnished a natural method of proving in perhaps even a better way what has been successfully demonstrated by the use of glass-caps, namely, that the apex of the root is the region of perception of the stimulus of gravity.

STUDIES ON POLLEN, IV.

F. M. ANDREWS, Indiana University.

As this investigation of the pollen of various plants has progressed, new and improved methods and apparatus have been devised and used. The large number of plants studied and the many cultures made from each required more elaborate and rapid methods and for the sake of accuracy, arrangements which would provide uniform conditions. The old method of using paper cells, while effective, was soon discarded for the glass ring cell. These rings were conveniently attached to slides by means of paraffin. They had the advantages over the first form, that they could be conveniently and individually darkened or illuminated for certain investigations; would prevent desiccation; were somewhat more rapid and were less liable to accident. These glass ring cultures, however, involved more expense and were liable to the same lack of uni-