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serpent as a Totem of the god of rain. This is matter of speculation, but would not seem to be altogether unreasonable, when we take into consideration the mythology of all other barbarous tribes.

The people of this silent city were peaceful and depended largely upon agricultural pursuits for a livelihood; selecting their location for a village with a view to natural barriers, placing their sentinels on the commanding places on the top of bluffs, and building a fort for a place of last resort, when forced to retreat by the enemy. The great quantity of grinding stones and stone hammers found upon the ground would all tend to show that they were not a war-like people. The villages being located on high ground so far from water, it was necessary to have some means of carrying water, which was done in earthen vessels. These vessels were of so frail a nature, and were so frequently broken, that it is quite probable, the majority of the women of the tribe were well up in the ceramaic art.

Fragments of pottery are found everywhere, but no whole vessels; the fragments show that the clay was mixed with coarse sand or pounded shells and dried in the sun. Some pieces exhibit cord markings; other pieces were ornamented with a sharp stick or bone, and is not unlike Indian pottery generally.

Much more could be said about this Indian village, a minute description of the various excavations having been omitted. It is hoped, that as years roll by, enough light will be shed upon the past, to give us a clearer conception of the origin of these as well as other tribes of American Indians.

THE GROWTH-PERIODICITY OF THE POTATO TUBER.—

Conway MacMillan.

While a vast amount of research has been expended upon the physiology of tubers, bulbs, corms and fleshy roots, it is not clear that any extended observations have ever been made upon the method of growth of such an organ as the potato tuber. It is a well known fact that the growth in length of upright stems and various aerial organs is not regular, but exhibits a marked daily periodicity, the time of greatest average growth being not far from three o'clock in the morning, and most stems show a clearly marked diurnal period, unless this period is modified or obliterated

by etiolation, suffocation, anæsthesia, or some other abnormal condition. Upon this subject since the researches of Baranetski and Pfeffer much attention has been bestowed, and we know that besides the daily periodicity there is a grand period of growth for each organ of the plant, that some organs reach the grand period of growth more rapidly or continue in it longer proportionately than other organs or similar organs in other species or in the same species under different outward conditions. The growth in length of any organ therefore is not regular, but it is to be graphically represented as a wavy curve with an ascending portion, a climacteric portion and a descending portion. In all of the parts of this great area, the climax of which represents the grand period of growth, one must notice the rhythmic pulsations due to the daily growth period, and more or less synchronous with the alternating periods of light and darkness, of higher and lower temperature, of less and of greater oxidation.

Seasonal rhythms in the growth of girth of organs is well known in the ordinary woody stems of Dicotyledons and Gymnosperms when the increasing tensions of later months reduce the rate of growth below the rate of the earlier months. This periodicity is a more simple and readily explained form than those periodicities which have been alluded to. It is found principally in organs provided with a cambium cylinder and a relatively inextensible bark and is referred to merely by way of illustration. While the potato tuber which is to be considered has a cambium area, it can scarcely be said to have a cortical area at all analogous to that of the erect tree trunk. We shall not find the tuber, protected as it is, and growing during a single season, affected by the conditions of alternate freezing and thawing, wind-disturbing, and so forth, which have so much to do with seasonal periodicity of growth in girth of woody stems.

A few months ago the writer was struck with the entire absence of investigations into the manner of growth of tubers, and gave more attention, forthwith, to devising a method by which the gap in our knowledge of tuber-physiology might be filled, in part. After due deliberation a method was formulated and applied, with but imperfect results at first; but as experience became wider the imperfections were gradually remedied. In all of the experiments Mr. C. P. Lommen, student in biology, at the University of Minnesota, gave much assistance in setting

up apparatus, and by two or three helpful suggestions concerning certain technical difficulties which presented themselves in the course of our investigations. The method of research first adopted by us is described somewhat in detail in the *Botanical Gazette,* May, 1891; but upon this method certain improvements have been made. The apparatus used was the Baranetski self-registering auxanometer with electric-clock attachment, manufactured by Albrecht of Tubingen. At first both wheels of the apparatus were not employed but afterwards it was found that the two wheels could be combined in such a way as to multiply the tracings tenfold, and in our later experiments the wheel attached to the tuber-thread does not bear the tracing-needle but carries another thread on its large circumference which runs to the small circumference of the tracing-wheel. By this means hourly registrations were obtained instead of three-hour registrations as by the first method.

To recapitulate the method finally adopted as developed: A potato plant grown in a box from which one end had been removed was selected and carried to the experimenting room. With due care a tuber was exposed, and under it, resting upon the bottom of the box, a wooden block was placed in such a way that downward pressure would not disturb the position of the tuber. The rootstock umbilicus was protected from desiccation or injury during these processes of blocking up. Next a wooden-jacket consisting of two squares of cigar box material held together by a number of slightly stretched rubber bands was fitted over the tuber, in such a way that one square of the cigar box wood lay upon the block below and the other was parallel with it, but on the opposite side of the tuber. To the center of this upper square a screw was fixed and to this screw a silver wire was tied—since thread was rotted by the soil—and this wire after the whole apparatus of block and jacket was covered with soil, came to the surface of the soil under the first wheel of the auxanometer. An inch or two above the ground a twisted linen thread which gave better friction on the wheel was attached to the silver wire, and this twisted thread was passed over the small circumference of the first wheel and drawn taut by a weight of about forty grams. Passing from the large circumference of the first wheel to the small circumference of the second was a linen thread equally weighted at each end and over the large circumference of the

second wheel was passed the thread bearing the tracing needle at one end and a small counterpoise at the other. The tracing needle was brought up against the smoked cylinder of the registering apparatus. This rested upon a clock-work in which a rachet-wheel was caught by a lever attached by a spring and bearing at the opposite end an armature near the poles of a small electro-magnet. Connected with the electro-magnet was a battery, but interpolated in the circuit was the electric clock so adjusted that every hour the circuit was closed for a few seconds. During the closure of the circuit the electro-magnet attracted the armature, overcoming the tension of the spring and releasing one cog of the ratchet wheel. By this means the cylinder attached to the clock-work turned about 1-16 of an inch, with the hands of the watch, and the tracing needle made a horizontal mark upon the smoked paper covering the cylinder. The opening of the circuit as the hands passed the hour released the armature, allowed the spring to push back the lever and stopped the cylinder clock-work until the next hour when a similar horizontal mark was made. During the hours, then, any expansion in the potato-tuber would loosen the string attached to the jacket. Pulling against this the weights would turn the first wheel. This would turn the second wheel and the indication of growth 100 times magnified, but in proper ratio would appear as vertical tracings upon the smoked cylinder. This brief description of the Baranetski apparatus is given that the exact method of research may be apparent.

The first experiments upon the growing tuber, made in accordance with the method described in the *Botanical Gazette,* were satisfactory in so far that they demonstrated the availability of the Baranetski apparatus for the purpose for which it was employed. In one of the early experiments a trace of periodic growth was distinguished, but it did not seem to be sufficient to base any confident assertion of periodicity upon. The first experiment continued two weeks. During this time the needle kept falling and at the close of the experiment was about half an inch below the level of the beginning. In the second experiment certain drops in the tracings, usually in the early morning, were noticed, but I have come to believe that these were not true growth-tracings but due to changes in temperature of the soil, the strings and the atmosphere with consequent shortenings and expansions. Against such accidental and confusing records as these it was constantly

necessary to guard. In general the conclusions from experiments with the single wheel were conservatively stated as follows:

(a) The apparatus as set up indicates growth, by cylinder tracings.

(b) A possible trace of periodicity in the growth might have manifested itself.

Further than this we did not feel at liberty to go, under the conditions of the experiment.

Desiring to obtain more perfect results and to solve the question of the manner of growth of the tuber, the improved method of setting of the apparatus described above was developed, and the first experiment gave very favorable and luminous results.

The experiment began with a tuber about ¾ inch in diameter. At this time the top of the plant had begun to die from the attack of a blight. After attachment the registering needle gave two or three sharp drops owing to the stretching of strings and general getting-into-equilibrium of the apparatus. After this stage was passed the needle began dropping very gradually. This gradual descent was continued from 8 o'clock in the evening until about 8 o'clock in the morning. At this time the drop ceased and horizontal tracings continued until about 1:30 p. m., when a short abrupt drop was registered, followed by a longer drop, then by one shorter than the second but longer than the first, next by one longer than any, closely succeeded by another long one. After this the registrations were short and the regular gradual fall until 8 a. m. began. Here again the horizontal mark began and continued until 2 p. m., when a second drop began, on a somewhat smaller scale than the one registered the first day. The total extent of the second day's maximum between 2 p. m. and 8 p. m., was about one-half that of the first day's maximum. The third day the same tracings continued—only the tracings of the maximum were very much reduced—not more than one-quarter, in total length, of the second day's tracings. The fourth day's tracings were like those of the second day in all particulars, and those of the fifth day likewise, except that the tracings showed a less maximum growth. The sixth day was peculiar. During this day no appreciable drop in the tracings was detected. The explanation of this cessation is not offered. It may be said, however, that the death of the top was now about complete so far as the leaves and secondary branches were concerned. Only in the

lower part of the main stem was living, green tissue still to be found. During the whole twenty-four hours little divergence of the tracings from the horizontal could be seen, but during the succeeding twelve hours a slight drop began. At 7 a. m. of the seventh day a decided drop began continuing until 11 a. m. There then succeeded a period of gradual dropping which disappeared about 3 p. m. Another drop took place in the evening from 6 to 9 p. m. The eighth day began with a drop at 7. a. m., continuing until 11, when three hours of horizontal marks followed. At 2 p. m. a five-hour drop began, and continued as a gradual depression, until 10 a. m. At 7 a. m. another abrupt drop took place, terminating at 11:30 a. m. At 3 p. m. a gradual drop lasting until 8 p. m. followed. During succeeding days the same rhythm continued, only the drops became slighter and slighter. Finally the needle ceased to trace. The explanation of these very curious maxima and minima in the growth of the tuber is a complicated matter. It can be given as yet only conjecturally. Before passing to any such conjectures, it may be well to give the conclusions arrived at in the experiment described above:

(a) The increase in diameter of the potato-tuber is not regular but is rhythmic.

(b) Maxima of growth are not of long duration, and are followed by periods of slower growth or of entire absence of growth.

(c) Maxima of growth may occur either once or twice and perhaps oftener during twenty-four hours.

(d) The maxima of some days are greater absolute maxima than those of other days. This indicates a grand period for the tuber.

(e) Regular periodicity in the tuber continues after the periodicity of the aerial stem is lost.

(f) Connected with profound changes of condition in the aerial stem changes in the periodicity of the tuber may be noted.

(g) There is some connection between the periodic growth of the tuber and the periodic growth of the aerial stem. What this connection is does not appear.

(h) There is also, it is probable, an *independent* periodicity in the growth of the potato-tuber which is obscured and modified by the secondary *induced* periodicity which is connected with the aerial-stem conditions and mode of growth.

With reference now to the conjectural explanation of the periodic growth of the potato-tuber, very little can be expected at this stage of the investigation. Whether like embryonic plants of *Hedera,* with their heliotropic irritability, the potato-tuber retains somehow, in hereditary fashion, its above-ground periodicity and thus gives hint of the time when its precursors were exposed to rhythmic alternation of light and darkness, is entirely an open question. On the other hand it is equally uncertain whether the induced periodicity is due to one or many causes. Some of the lines of research are indicated below and it is hoped that they will be followed to their rational conclusion.

(1) The rhythm of assimilation in the above-ground stem may affect the growth of the below-ground tuber. The synthesis of carbohydrates is a diurnal affair. From these carbohydrates the substance of the tuber is formed. Thus the rhythm above might induce a rhythm below.

(2) The conversion of plastic materials into reserve materials is characteristic of an organ like the tuber. This conversion depends upon the activity of certain ferments which are results of destructive and constructive metabolic changes in the shoot-area. These metabolic changes are connected with the respiration-function and this is a periodic or rhythmic function.

(3) The growth of the above-ground stem is strongly periodic and demands, in any plant, the same kind of material which would be supplied to a growing tuber. This drain upon the plastic-material in one direction might induce a corresponding dearth of it in another so that the periodic growth of the above-ground stem might induce a periodic growth in the below-ground tuber.

(4) The asynchronous grand-periods of growth of the different above-ground organs might be reflected in an irregular and erratic periodicity in the below-ground tuber.

(5) Combinations of these various conditions and a modification of them all by the independent rhythm of the tuber itself would have to be considered, and only by the most elaborate and extended researches could the proximate causes for the observed tuber-periodicity be detected.

In closing this contribution to the physiology of tubers one word by way of note may be added. It is possible to apply

auxanometer methods to root-stocks by uncovering the root-stock attaching a silver thread, running it horizontally to the open side of the box passing over a horizontal roller and upward and finally adding the linen (or silken) thread which runs on the small circumference of the first wheel. Or in this case one wheel alone could doubtless be used. This study of underground stems, as in the grass root-stock, the potato rhizome or any other underground stem, would throw some light upon the tuber and its method of growth. A comparison of underground organs should be made along this line.

May 5, 1891.

PRELIMINARY NOTES ON THE EPINASTY AND HYPONASTY OF RAPHAINUS COTYLEDONS.—*E. P. Sheldon.*

In presenting this evening some of the phases of our present knowledge regarding the various positions assumed by dorsiventral organs during their period of growth and development, I think I can do little better than to give a short outline of the views held by prominent botanists on this point, and follow somewhat the course of development of such views as outlined by Sydney H. Vines, in his article on Epinasty and Hyponasty.*

First in importance are the views of De Vries.†

Here we have the first recognition of the fact that the growth of the two sides of a dorsiventral organ is not equal. There may be some growth on both sides of such an organ, but when the growth of the upper side preponderates over the growth of the lower organ it is said to be in a state of epinasty. When the reverse is true it is said to be in a state of hyponasty.

De Vries does not agree with Frank‡ in regard to the cause of the position of such members.

Instead of explaining their position by peculiar forms of geotropic and heliotropic irritability, he considers them as a resultant of the various forms of epinasty, hyponasty, and negative or positive heliotropism or geotropism. The observation of Sachs§ on

*Annals of Botany. Aug., 1889.

†De Vries: Arb. d. bot. Inst. in Würzburg, 1, 1874.

‡Frank: Die natürliche wagerichte Richtung von Pflanzentheilen Leipzig, 1870.

§Sachs: Arb. d. bot. Inst. in Würzburg, 11, 1879.