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Established 1897

Edited by
FORREST SHREVE

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THE RELATION OF TRANSPIRATION AND STOMATAL MOVEMENTS TO THE WATER-CONTENT OF THE LEAVES IN *FOUQUIERIA SPLENDENS*[1]

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In a previous paper[2] I stated that the error due to the use of the potometer in studying transpiration in *Fouquieria splendens*, as indicated by comparative weighings, fell for a total of twenty-four hours below a maximum of 4 per cent, and that this error was so distributed as not to affect the general character of the curve of transpiration rates. This outcome of my control experiments at that time was the sole consideration, and I did not, therefore, examine any further into the possible meaning of the discrepancies noted.[3] It was, however, obvious that there must be some proper explanation of them. Either they must have been due to accidental circumstances, such as possible temporary obstructions in the path of the water current in the stem or the wilting of the leaves; or they must represent some changing ratio, due to normal causes, between the water received by the leaf and that exhaled by it. I had previously excluded, to my own satisfaction, the possibility of plugging at the cut end of the stem, by a simple method already described in my paper cited above. A reëxamination of a part of the data there published indicates that the latter alternative is more likely correct, from the fact that water was retained by the plant during the night, while the reverse occurred in the daytime. This result might have been ascribed to the behavior of the stomata, or to some other cause, but any

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[1] Read by title at the annual meeting of the Botanical Society of America, Minneapolis, Minn., December, 1910. Digest in Science, n. s., 33: 191. 3 Feb., 1911. Ref. in Expt. Sta. Record **25**: 124. Aug., 1911.

[2] The Physiology of Stomata. Carn. Inst. Wash., Publ. 82.

[3] Lloyd, *l. c.*, p. 20.

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attempt at explanation would have involved experimentation *ad hoc*, which was impossible at the time. As the ocotillo (*Fouquieria splendens*) was the subject of study, no further opportunity was presented for additional investigation till the summer of 1910, when, at the courtesy of the Carnegie Institution of Washington, I was able to extend my study of this plant at the Desert Botanical Laboratory. The purpose to determine the ratio, hour by hour, between the volumetric and gravimetric readings was then carried out.

In making these and the synchronous instrumental readings I had the assistance of Dr. W. H. Brown. The drawing for the accompanying figure was kindly prepared by my colleague Mr. C. G. Gaum. To these gentlemen I tender my thanks.

In addition to these readings made for three pieces, material for studying the condition of the stomata was taken at suitable intervals, pieces of epidermis being fixed by absolute alcohol, the method previously used. (Lloyd, *l. c.*) The whole series of readings extended for the space of twenty-seven hours, beginning at 7 P.M., August 21. The data presented in the tables are those for the twenty-four hours beginning at 10 P.M. Three pieces of ocotillo, each about 50 cm. long, were carefully selected from good plants which were evidently well supplied with soil moisture, as they were in full leaf, well colored, and showed no signs of yellowing. A slight change in color from green towards yellow indicates that the plant is beginning to respond to a lessening water supply. The selected pieces were set up in burette potometers, as described in my earlier paper, and, after noting that the changes in the rates in the three pieces were approximately parallel, they were regarded as ready for use. All the readings were made in the same rotation each hour. When all the readings had been recorded, each piece with its attached burette was carefully weighed. Immediately at the close of each weighing a second reading was recorded, to serve as a check on the first reading and for close comparison with the gravimetric data. This was of course necessary, since the intervals between the hourly volumetric readings and those obtained by weighing were not quite equal. The pieces were set out in the open, and remained there during the whole period of observation, except that the pieces were carried into an adjoining building, where they remained a minute or two during weighing. The time error introduced amounted at most to about three minutes, but this error practically disappears by making the burette reading at the conclusion of the weighing.

In the tables following, the first readings, namely those made precisely on the hour have been omitted, since their introduction will serve no useful purpose. They have, however, been carefully compared with the readings following the weighings, in order to detect errors. No such errors, which would most likely have occurred during periods of rapid transpiration, sufficient to disturb the validity of the data which are here presented, have been observed. In plotting the graphs (fig. 1) it was assumed that the intervals between the readings (with conjoint weighings) are equal. It is probable that this assumption is correct within 3 per cent.

Regarding the use of the potometer for the ocotillo, it emerges that the differences between the lowest and highest rates, determined by volume, are less than those determined by weight (in the ratio of 27 to 28 for piece 1, approximately). This is seen at a glance by comparing the course of the corresponding graphs in the figure. For the purpose intended in my earlier work, the error due to the use of the potometer in the study of this plant is, therefore, on the right side of the balance sheet, and my inferences, based on the data earlier published, unless invalidated by other evidence, are true.

It appears further that the error, due to the use of the potometer, relatively to the total loss of water during a part of the night, amounts to 50 per cent, that is, about one-half the small volume of water taken up by the plant, when the rate of transpiration is extremely low, is retained within it. This may be regarded as due chiefly to the damping effect of the closed or nearly closed stomata or of other physical conditions in the leaf, or to the less favorable conditions for evaporation. That the rate of transpiration during the night, as compared with that of evaporation from three atmometers (the data for one of them being given in table VI) is more uniform indicates that there is some factor at work in

TABLE I

Fouquieria splendens. Transpiration measured by volume of water absorbed and loss by weight. Piece No. 1, August 21-22, 1910

HOUR	LOSS IN		DIFFERENCES IN WEIGHT OF PLANT	
	Volume	Weight	+	–
	cc.	*gms.*		
23	0.8	0.89		0.09
24	0.75	0.34	0.41	
1				
2	0.85	0.59	0.26	
3	0.30	0.26	0.04	
4	0.35	0.27	0.08	
5	0.40	0.26	0.14	
6	0.75	0.89		0.14
7	1.50	1.65		0.15
8	4.20	4.43		0.23
9	7.30	7.62		0.32
10	7.85	7.39	0.46	
11	7.45	7.89		0.34
12	8.30	8.76		0.46
13	8.50	8.41	0.09	
14	5.80	6.13		0.33
15	5.05	5.23		0.18
16	3.25	3.32		0.07
17	3.10	3.30		0.20
18	2.50	2.47	0.03	
19	1.90	1.90		
20	1.70	1.80		0.10
21	1.35	1.20	0.15	
22	0.95	0.65	0.30	
Total			2.16	2.61

Net loss: 0.45 cc. Weight of piece, about 80 grams.

the plant, or several factors, absent from the purely physical instrument. Indeed, throughout the whole period of observation, the responses of the former are less abrupt than those of the latter. It appears quite certain, therefore, that the physical peculiarities of the leaf are, in part at any rate, the responsible factor, but the separation of the stomatal influence, due to changes in dimensions (which are very limited), and that due to the banking up effect

TABLE II

The same. Piece No. 2

HOUR	LOSS IN		DIFFERENCES IN WEIGHT OF PLANT	
	Volume	Weight	+	−
	cc.	*gms.*		
3	0.90	0.94		0.04
24	0.8	0.45	0.35	
1				
2	0.90	0.58	0.32	
3	0.30	0.26	0.04	
4	0.50	0.36	0.14	
5	0.50	0.36	0.14	
6	0.95	1.02		0.07
7	1.85	2.04		0.19
8	5.60	6.04		0.44
9	10.40	11.10		0.70
10	9.00	8.96	0.04	
11	7.30	7.64		0.34
12	6.75	7.19		0.44
13	7.15	7.21		0.06
14	5.15	5.17		0.02
15	5.35	5.31	0.04	
16	2.80	2.84		0.04
17	3.25	3.29		0.04
18	2.65	2.49	0.16	
19	1.80	1.60	0.20	
20	1.50	1.30	0.20	
21	0.95	0.70	0.25	
22	0.70	0.40	0.30	
Total......................................			2.18	2.38

Net loss: 0.2 cc. Weight of piece about 80 grams.

within the intercellular passages is more difficult, and is, further, not within the purview of the present paper.[4]

It is obvious that, if small differences in low rates of evaporation from the leaf alone were to be determined in the ocotillo, the potometer method would not be available. This is true also for any short intervals during which little change in rate occurs. Large changes during relatively short intervals, however, are registered

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[4] See also Livingston, B. E. Carn. Inst. Wash., Publ. 50.

TABLE III

The same. Piece No. 3

HOUR	LOSS IN		DIFFERENCES IN WEIGHT OF PLANT	
	Volume	Weight	+	−
	cc.	*gms.*		
23	2.20	2.26		0.06
24	1.50	1.15	0.35	
1				
2	1.95	1.78	0.17	
3	0.75	0.68	0.07	
4	0.70	0.74		0.04
5	0.90	0.80	0.10	
6	1.80	1.81		0.01
7	2.90	3.14		0.24
8	8.30	8.55		0.25
9	13.30	13.7		0.40
10	11.90	11.5	0.40	
11	11.60	11.93		0.33
12	13.30	13.25	0.05	
13	16.35	16.20	0.15	
14	12.35	12.39		0.04
15	12.70	12.73		0.03
16	7.35	6.91	0.44	
17	8.75	9.00		0.25
18	6.90	6.84	0.06	
19	3.70	3.75		0.05
20	3.50	3.35	0.15	
21	2.20	2.35		0.15
22	1.60	1.40	0.20	
Total..			2.14	1.84

Loss not regained: 0.3. Weight of piece, about 140 grams.

with relatively small error. For the present, also, the potometer serves, when the data derived by it are compared with the data derived gravimetrically, to disclose, with a high degree of accuracy, a constantly changing ratio between the water transpired and that taken up, as follows.

During the hours of the night, the intake of water is constantly in excess of the outgo. At some moment between the hours of five and six in the morning, the rates are equal. During the earlier part of the day the outgo is in excess of the intake.

TABLE IV

Fouquieria splendens. Reading in tables I to III, inclusive, calculated to uniform rate (100) 2–3 hour, August 21–22, 1910. Tucson, Arizona.

HOUR	LOSS IN					
	No. 1		No. 2		No. 3	
	Volume	Weight	Volume	Weight	Volume	Weight
23	2.66	2.97	3.0	3.13	2.93	3.0
24	2.50	1.13	2.7	1.5	2.00	1.5
1						
2	2.83	1.97	3.0	1.9	2.6	2.4
3	1.00	0.87	1.0	0.9	1.0	0.9
4	1.16	0.90	1.67	1.2	0.93	1.0
5	1.33	0.87	1.67	1.2	1.2	1.1
6	2.50	2.97	3.20	3.4	2.4	2.4
7	5.0	5.5	6.2	6.8	3.9	4.2
8	14.0	14.8	18.6	20.1	11.0	11.4
9	23.98	25.4	34.7	37.0	17.7	18.3
10	26.2	24.6	30.0	29.9	15.9	15.3
11	24.8	26.3	24.31	25.5	15.5	15.9
12	27.7	29.2	22.5	24.0	17.7	17.7
13	28.3	28.0	23.8	23.7	21.8	21.6
14	19.3	20.8	17.2	17.2	16.5	16.5
15	16.8	17.4	17.8	17.7	16.9	17.0
16	10.8	11.1	9.3	9.5	9.8	9.2
17	10.32	11.0	10.8	11.0	11.7	12.0
18	8.32	8.2	8.8	8.3	9.2	9.1
19	6.33	6.3	6.0	5.3	4.9	5.0
20	5.7	6.0	5.0	4.3	4.7	4.5
21	4.5	4.0	3.2	2.3	2.9	3.1
22	3.15	2.17	2.3	1.3	2.1	1.9

It is probable that, for days of continuous sunshine this relation continues till from one to four in the afternoon, during which period the rates, while not equal, vary only very slightly in either direction. On the day during which the observations were made the sky was obscured by a haze, which began to appear at about 8 A.M., and lasted until after ten. The effect of this diminution of light was recorded by three atmometers in a fashion similar, broadly speaking, to that of the pieces. The rates of evaporation displayed by one of the atmometers, a blackened porous cup,[5]

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[5] Livingston, B. E. A Radio-atmometer for Comparing Light Intensities. PLANT WORLD, 14:96–99. Apr., 1911.

placed perpendicularly to the plane of the sun's apparent path, are given in table V, and the graph for these is plotted in the figure. The reduced evaporation, largely due to reduced light, recorded by the radio-atmometer, is paralleled by the transpiration curve as determined *by weight,* and the conditions were evidently such

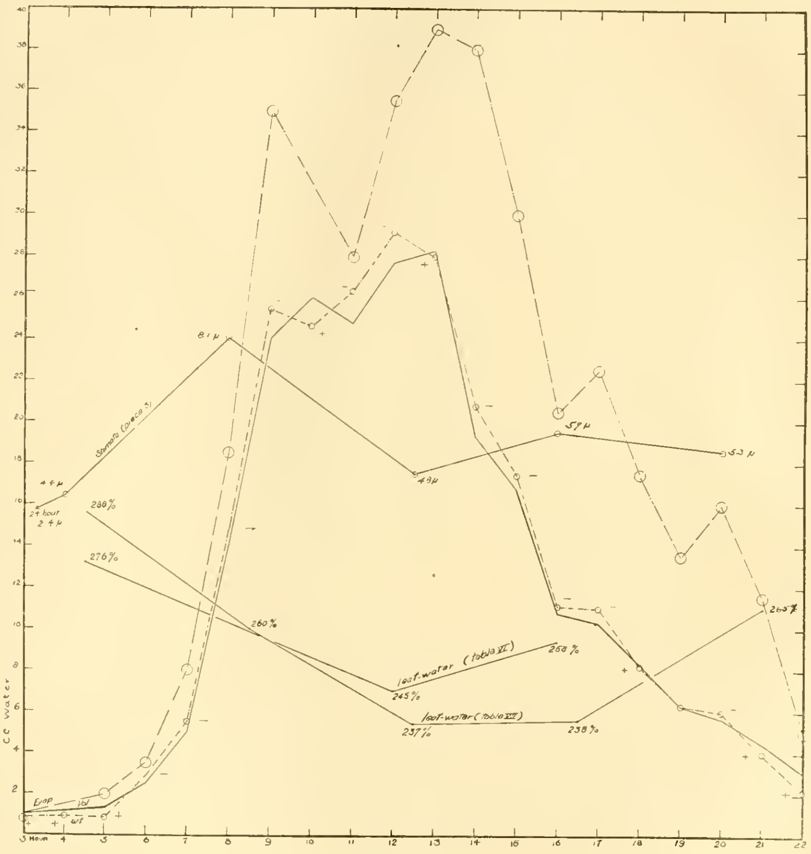

Fig. 1

as to enable the leaves to exert a damping effect on transpiration and, as a result, to retain some of the water received by them. This is true for the 9–10 hour for all three pieces. For the 12–13 hour, the increase in evaporation was accompanied by retention of water in piece 1 (fig. 1) and in piece 3, but by a slight loss in piece 2. Pieces 2 and 3, however show a *rise* in transpiration and in this behave like the radio-atmometer. Between these hours, namely from 10 to 12, lies, for the day of observation, the period of maximum net loss of water, and this would, under a clear sky, doubtless be extended from 9 to 13, unless some behavior in the plant should enter in to reduce the evaporation from the leaf. That such a factor may intervene is suggested by the various behavior of the pieces during the 12–13 hour. That stomatal movement is not the determining factor seems to be excluded by the data on stomatal behavior in hand. That conditions within the leaf may work to this end is quite probable, among which that of the cell walls under a relatively low vapor tension within the intercellular spaces is probably very important.[6]

From the thirteenth hour on till about sunset the two rates are nearly the same, but, while there is some vacillation, there is a pretty constant though very small net loss of water. Something must be allowed for error, but scarcely more than 0.05 cc. The size and distribution of the ratios compel the conclusion, therefore, that the amount of water in the plant fluctuates from hour to hour. Eberdt[7] came to a similar conclusion, finding corresponding day and night fluctuations in *Helianthus annuus*, from which the inference was drawn that the water-loss through the foliage and the intake through the roots are two different things, but no light is thrown on the seat of low tension. One may suppose the fluctuation to be either in the stem (involving negative pressure as ordinarily conceived) or in the leaves, or in both. As the leaves in the experiments being considered did not betray any

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[6] Livingston, B. E. Relation of the Daily March of Transpiration to Variations in the Water Content of Foliage Leaves. Bot. Gaz. In press. For a sharply analytical study of the relation of water in leaf and stem, see Renner, O., Experimentelle Beiträge zur Kenntnis der Wasserbewegung. Flora, **103**: 171–247. 1911. That, under the conditions of the experiments described in the present paper, the fluctuations in water-content are probably referable very largely, if not entirely, to the leaf is supported by Renner's experiments on the influence of the length of the stem on the absorption of water by the leaf (Renner, *l. c.*, p. 204). Renner also finds evidence, obtained by other methods, for concluding that "in transpirierenden Blättern besteht also immer ein Sättigungsdefizit" (*l. c.*, p. 243).

[7] Through Burgerstein, A. Die Transpiration der Pflanzen. Jena. 1904, p. 17.

visually appreciable flaccidity, the fluctuation in question is apart from the loss from wilting in the usual sense and may be considered chiefly as a fluctuation above and below a normal, or perhaps better, average quantity. That however this fluctuation is, for the far greater part, within the leaf, and not the stem would be expected from the fact that the potometer was used, and this is shown by a determination of the amounts of water in the leaves of the ocotillo at various times of the day and night.

The method employed was the following. Leaves were collected into a tared bottle, and the fresh and dry weights determined. The amount of water was calculated to the dry weight of the leaves. The results obtained from six series, three on each of two different occasions, on August 11 and August 16 are given in tables VI and VII respectively, from which it is seen that the percentage of water to dry weight varies from about 225 to 300 per cent as extreme limits as between day and night. The two curves in the figure are for the average of the members of the two series taken separately. They show that the diminution in the amount of water in the leaf begins at daybreak and continues until sometime between noon and 4 P.M. The behavior of the leaf in this regard is in general harmony with that indicated by the transpiration curve during the earlier half of the day, namely, that the outgo of water exceeds the income. The period of recovery, however, as indicated by leaf-water determinations is not as evidently indicated by the transpiration data, save, probably by piece 3, in which there was a substantial net gain. In pieces 1 and 2 there was a net loss. This partial discrepancy may be explained on the theory that the net loss in the afternoon is felt by the stem-tissues rather than those of the leaves, these experiencing a net gain. However, it must be remembered that the leaf samples were obtained from other plants, *in situ*, on other days than that in which the transpiration observations were made. Should there have been some interference to the entrance of water into the cut surface of the stem in the potometer pieces (and this, in spite of the precaution taken, is not unlikely), it is quite possible that a state of negative pressure might have made itself evident in the stem, while the increasingly less favorable conditions for

TABLE V

Black horizontal. Atmometer rates reduced to unity, 2–3 hour. August 21, 1910.

HOUR	RATE	HOUR	RATE
	cc.		*cc.*
23	15.0	11	28.0
24	11.0	12	35.5
1	3.5	13	39.0
2	3.0	14	38.0
3	1.0	15	30.0
4	2.5	16	20.5
5	2.0	17	22.5
6	3.5	18	17.5
7	8.0	19	13.5
8	18.5	20	16.0
9	35.0	21	11.5
10	31.5	22	5.0

TABLE VI

Fouquieria splendens. Tucson, Arizona, August 11, 1910. Percentage of water to dry weight of leaves, taken from a zone of a branch at the same distance from the ground, for three different individuals.

HOUR	PIECE 1	PIECE 2	PIECE 3	AVERAGE
12, August 11	242.1	266.8	223.6	245
16, August 11	258.0	277.4	239.3	258
4:30, August 12	274.2	303.8	249.22	276

TABLE VII

Fouquieria splendens. Tucson, Arizona, August 18, 1910. Percentage of water to dry weight in the leaf, in three different individuals. 1, An old, thick stem; 2, A young, thin stem; 3, Medium stem.

HOUR	PIECE 1	PIECE 2	PIECE 3	AVERAGE
4:30	295.2	288.7	279.6	288
8:30	288.0	258.0	233.4	260
12:30	248.8	243.0	217.9	237
16:30	251.3	226.4	235.7	238
21	279.7	251.1	263.3	265

transpiration would at the same time assist the leaves in increasing their water-content.

Whatever may be the true explanation, there is a high probability that the loss of water from the leaf in the morning is approximately a measure of the excess of outgo over intake of water as indicated by the gravimetric and volumetric data. It is scarcely less probable that the reverse relations of the afternoon obtain under normal conditions, but a proof of either of these, in a strict quantitative sense, is still to be obtained.

It is obvious that, in estimating the amount of leaf-water in terms of dry weight, we are using a varying measure, increasing in value during a part or all of the day, due to photosynthesis. This would show a decrease in the relative amount of water, but, unless we assume that there is a decrease in the value of the measure (due to a loss of photosynthetic materials) after about midday, we cannot explain the rise in water content after that time except on the inference of an increase considerably in excess of the amount at sunrise.[8] That is, with a constant increase in dry weight, there should be a constant decrease in the relative amount of water. Data now on hand and in process of publication show that, in the cotton plant, there is generally an increase in dry weight, until mid-afternoon, at any rate, and probably until sunset. Should it develop that the same is true of the ocotillo, the inference would then be clear. It was my purpose in the summer of 1911 to make the determinations of dry weight and leaf-water per unit area of leaf in the ocotillo, but at the time of my visit, it had not sufficiently developed its leaves and I am therefore compelled to await further opportunity.

Finally it is of interest to note the behavior of the stomata. My conclusions at this time are based upon the measurements, kindly made for me by Mr. C. S. Ridgway, of 1800 stomata, 300 for

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[8] Fitting observed that the leaves of desert plants in the region of Biskra showed, in spite of the high osmotic pressures observed in them by him, a water content much below their capacity (Die Wasserversorgung und die osmotischen Druckverhältnisse der Wüstenpflanzen. Zeitschr. f. Bot. **3**: 209–275. 1911, p. 258). Whether the ocotillo exhibits the same condition remains to be seen, but it seems unlikely that under the conditions of the experiments here described, the water-content of the leaves in the afternoon would exceed that at sunrise.

each hour of observation, namely, midnight, 4 and 8 A.M., 12:30, 4 and 8 P.M. The average length of the pore is constant (20 microns). The average width is indicated for each hour in the curve. If the probable errors were calculated, the shape of this curve would be slightly altered, but not sufficiently to change it materially.

It is to be noted that there was an opening of the stomata between midnight and sunrise, from 2.4 to 4.4 microns. This agrees with my previous observations on the same plant[9] and with the recently published data of Darwin and Pertz[10] on *Nicotiana* and *Prunus*, obtained by means of the porometer.

Between 4 A.M. and 8 A.M., the opening movement is continued till an average maximum opening of 8.1 microns is attained. At 12:30 P.M. the stomata were found to have closed to about 5 microns, after which but little change was noted. The behavior during the latter part of the day cannot with certainty be regarded as wholly normal as it does not accord with my previous results. For the sake of considering the question in hand, we may make the assumption that there was a steady closure between 1 and 4 P.M., from 5 to 2 microns, and treat it alternately with the apparent fact of the case.

One sees that during the period of stomatal opening, the plant suffers a measurable net loss of water, and it seems in a high degree probable that this loss takes place in the leaf. The diffusion capacity of the stomata is therefore so great as to allow a condition which may be regarded as preliminary to that of wilting. The stomata during the morning hours are not effective in keeping up the supply of leaf-water to a definite amount. The loss of water, indeed, continued with the interruptions noted, during the whole day till toward sunset, so that, even on the assumption made in the preceding paragraph of stomatal closure during the afternoon, the stomata, during closing, are at any time still not effective in shutting off the loss to the plant. It would seem, therefore, that the increase in water-content of the leaf in the afternoon depends

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[9] Publ. 82, Carn. Inst. Wash.

[10] On a New Method of Estimating the Aperture of Stomata. Proc. Roy. Soc. B. **84**: 136–154. 1911.

more upon surrounding physical conditions than upon the stomata. If, on the other hand, we accept the data as they stand, the rôle of the stomata in regulating the leaf-water is still more negatived.

CONCLUSIONS

Comparative volumetric and gravimetric data show that in the ocotillo, the ratio between the intake and outgo of water is not a constant, but that the outgo during the day is greater than the intake. The reverse relation obtains during the night.

The amount of water relative to the dry weight of the leaves decreases till noon or sometime thereafter, and then increases till 4 A.M., approximately.

The change in water-content of the leaf explains, in part at least, the discrepancy between the income and outgo of water.

The decrease of water in the leaf occurs during the opening of the stomata. These organs are, therefore, not closely regulatory of the loss of water from the leaf and are ineffectual in maintaining a constant supply of leaf-water. Transpiration is, therefore, at times too great, and the stomata do not serve to reduce it by closing movements; they may, however, limit it in a purely passive manner.

SOME ANCESTORS OF THE PERSIMMON

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The Ebony family or Ebenaceae of the order Ebenales is comparatively large, with upwards of three hundred different species distributed among five or six genera, more than half of them being referable to the genus *Diospyros* to which our common eastern form belongs. The name *Diospyros* is derived from the Greek and means God or life-giving or heavenly. Its selection for these particular plants required the same type of imagination which gave to our common clams the name *Venus*, and which saw the mythical shapes embodied in the constellations. Most of my readers are familiar with our American persimmon or "Possum wood" and not a few will recall the extremely astringent taste of its unripe fruits. Many are also familiar with the large edible persimmons of China and Japan which are now often cultivated in our extreme southern states. Persimmon wood is hard and strong and is used to a considerable extent in the manufacture of bobbins and similar articles. This quality of hardness and fineness of grain runs through the whole family and the bulk of the ebony of commerce is derived from various species of *Diospyros.* According to the writer of the book of Ezekiel, ebony was one of the articles of merchandise of the Phoenicians and the ancients esteemed it even more than we do at the present time. Virgil and Pliny mention it as a product of India and Herodotus relates that it was one of the articles of tribute in the days of the Persian empire. Naturally a wood which has been utilized for so long, a wood so fine-grained, hard, and heavy, and susceptible of such a high polish, was thought to possess many mystic virtues. It was used for making scepters, images and drinking cups because of its supposed antagonism to poison. Pausanius relates that the ebony tree produced neither leaves or fruit, nor was ever seen exposed to the sun.

The species of *Diospyros* and indeed the entire family to which it belongs are, for the most part, confined to tropical and subtropical countries. The different species of persimmon or ebony are widely distributed and indigenous to all of the continents. At first sight, it seems singular that a tree whose near relatives are all tropical should be found ranging from Florida and Texas, northward to southern New England and to Iowa and Kansas in the West. It is clear that present climatic conditions altogether fail to explain such a range. Nor is it to be accounted for by the supposition that the persimmon has extended its range northward from the tropics during the few thousands of years which have intervened since the last glacial epoch. Like so many of our other American trees, the real explanation is to be sought in the records which are far older than those of post-glacial times. Fortunately the persimmon has left many such records of its former distribution extending back some millions of years previous to the advent of man on this earth.

In that grand display of dicotyledonous genera which during the mid-Cretaceous replaced the old Mesozoic flora of ferns, cycads, and conifers and which appeared with such apparent suddenness at a number of points in the northern hemisphere, we find unmistakable evidence of the abundance and wide distribution of species of *Diospyros*. No less than fourteen different forms have been described from the rocks of this age, and the localities where they have been found are scattered from Australia to Bohemia, Greenland, and Vancouver Island. A large majority of these species are American, and they seem to have been especially at home along the Cretaceous coast of the Atlantic and along the border of the mediterranean sea which extended northwestward from the Gulf of Mexico over much of our present Great Plains area. One of these species, well named *Diospyros primaeva* by Professor Heer in 1866, is especially widespread and abundant, being found not only in Iowa, Kansas, and Nebraska in the west but also from Texas eastward through Alabama and northward in South Carolina, North Carolina, Maryland, New Jersey, Long Island and Greenland, or, from latitude 33° to latitude 71° north. That these early persimmons were not very different from those of today is shown by their similar foliage, as may be seen from a comparison of the leaf of *Diospyros primaeva* shown in fig. 1 alongside of a small leaf of our existing *Diospyros virginiana* (fig. 3). This resemblance is also shown by the fossilized remains of the calices of various species. One of these calices from another early Cretaceous species, recently described by the writer as *Diospyros vera* and found in what is known in the Potomac River valley, as the Raritan formation, is also shown in fig. 2. Apparently the habit of accrescence had not been fully formed but the calyx was persistent then as now and entirely like a modern calyx in appearance. It was four-parted as it usually is in existing persimmons, but other fossil forms had a five-parted calyx like a good many present day tropical species.

In the Eocene period, which succeeded the Cretaceous, the records of the fossil occurrences of *Diospyros*, show that it was truly cosmopolitan. These records include Siberia, Alaska and Greenland on the north, Canada, various localities in Europe, as well as Colorado, Montana, Wyoming, Nevada, Oregon, Washington, and other western states. A leaf of one of these early Eocene forms from Montana is shown in fig. 4. Unfortunately, we have no Eocene or later Tertiary records along the Atlantic coast of North America since the preserved deposits are all of marine origin and contain no fossil plants. There is little doubt, however, that *Diospyros* continued to be an abundant element in the arborescent flora of this area.

The Eocene was succeeded by the geological period known as the Oligocene in the rocks of which age no fossil plants have thus far been discovered in this country. In Europe, where the Oligocene is marked by a warm temperate climate and by shallow lake and river deposits, the remains of *Diospyros* are very common. The records include Greece, Germany, Italy, Austria, and France and embrace calices or leaves of at least fifteen different species. Especially in southern France where the climate approached subtropical conditions, numerous varieties of the persimmon flourished along the borders of the shallow gulf which extended up the Rhone valley. In succeeding Miocene time, a period of luxuriant forests, species of persimmon are found throughout Europe. In

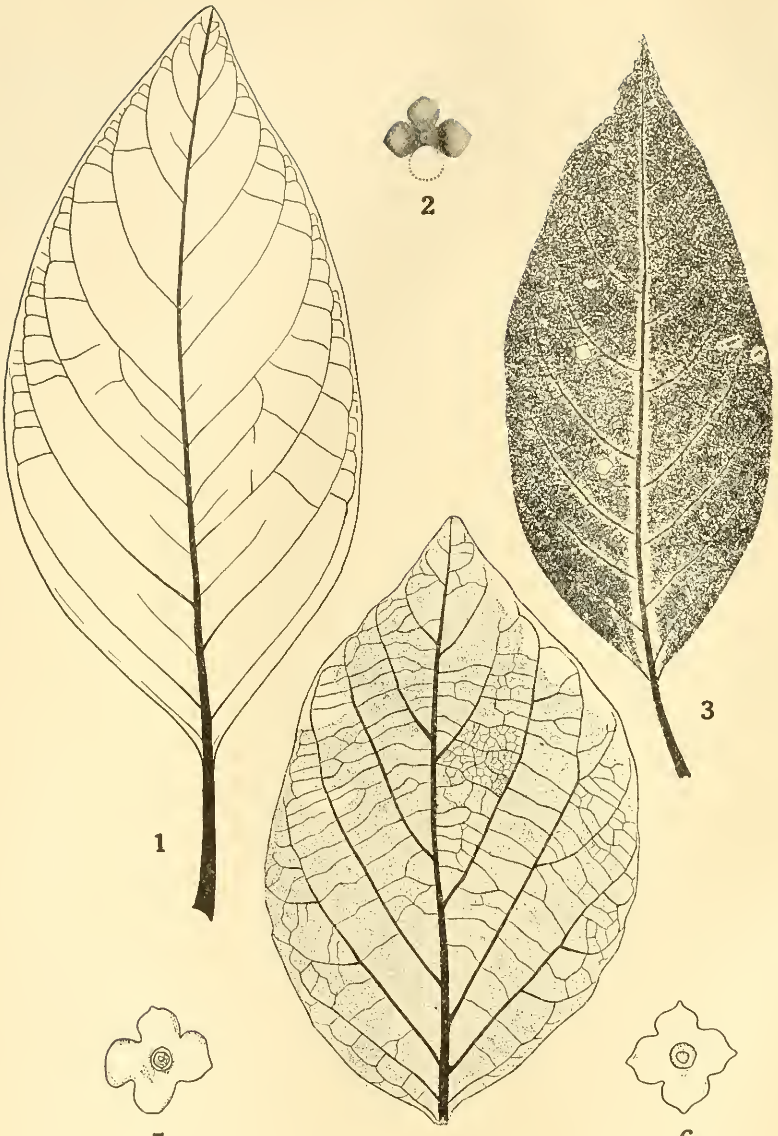

Fig. 1 Leaf of *Diospyros primaeva* Heer from the Raritan formation of New Jersey.

Fig. 2 Calyx of *Diospyros vera* Berry from the Raritan formation of the District of Columbia.

Fig. 3 Leaf-print of a small leaf of the existing *Diospyros virginiana* Linné.

Fig. 4 Leaf of *Diospyros ficoidea* Lesquereux from the early Eocene of Montana (after Ward).

Figs 5 and 6 Calices of *Diospyros brachysepala* Alex. Braun from the Miocene of Switzerland (after Heer).

America, where the Miocene records are very incompletely preserved, the persimmon is recorded from Montana, Colorado, California, and Oregon. The leaves of at least two species are preserved in the late Miocene upland lake basin of Florissant in the Rocky Mountains of Colorado. Specimens of *Diospyros* calices from the Miocene of Switzerland are shown in figs. 5 and 6.

The Miocene period was followed by the Pliocene, a time during which the American deposits appear to have been unfavorable, either because of their character or location, for the preservation of fossil plants, since practically none have been discovered. In Europe on the contrary, there were great fluctuations of the mediterranean sea which at one time covered most of southeastern Europe with its shallow waters. The climate was consequently equable and humid and the shores were well wooded, as is clearly indicated by the great abundance of fossil plants which were preserved. The persimmon continued to be an abundant element in these Pliocene floras, and no less than eight different species of *Diospyros* have been reported from deposits of this age. The localities include Italy, Spain, France and Austria, one of the French species being indistinguishable from our existing *Diospyros virginiana.* A fortunately preserved Pliocene deposit on the island of Java shows that then as now, *Diospyros* was a prominent element in the Malayan flora.

What happened at the close of the Pliocene, we can only conjecture, since we have no Pleistocene records of *Diospyros.* We know that their range was gradually restricted through cool northern climates, and by the gradual development of the plains type of country due to continental growth and to the elevation of mountain ranges which shut off the moisture laden winds. With the subsequent advance of the glaciers southward over Europe in Pleistocene time, and the glaciation in the mountains, Pyrenees, Alps, Carpathians and others, which with the Mediterranean sea shut off the retreat of the numerous Tertiary forms, *Diospyros* fared but ill on that continent and most of the species became exterminated. In America and Asia, a congenial habitat spread far to the southward of the ice-front and there were no dangerous mountain glaciers across their paths, consequently the persimmons were able to maintain themselves and to spread northward again in the wake of the ice sheet. In America, our common persimmon forsook temporarily its more northern haunts, although it is doubtful if its northern limit at any time was farther south than the Potomac River, since it is extremely probable that the extensive Pleistocene glaciation was due more to unbalanced precipitation than to any great degree of secular change in temperature.

Much more might be written concerning the geologic history of *Diospyros* and its migrations in the past, as well as something of the existing species,—their utility, beauty, and habits of life, but enough has been recorded here to show how immensely remote its forbears were and what an extensive territory its ancestors once occupied. In closing, let me repeat the cardinal fact first emphasized in Alfred Russel Wallace's work on distribution, that the present day geographical distribution of plants is almost entirely the end product of their distribution in antecedent geological ages and that there is the most complete dependence between

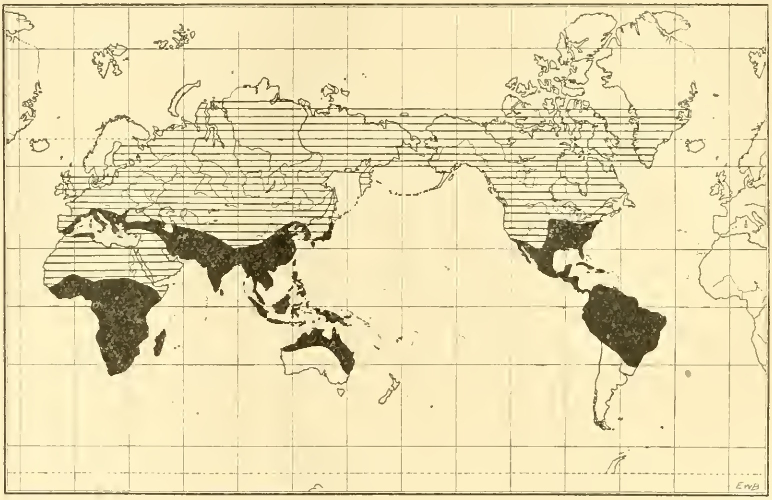

Fig. 7 Sketch map of the world showing the distributional areas of the existing species of *Diospyros* (solid black) and the more extended range of the fossil species (ruled lines).

their ancestral history and the geologic, geographic, and climatic history of the earth.

I have attempted to summarize the history of *Diospyros* in a graphic way on the accompanying small sketch map of the world (fig. 7). The solid black indicates the distributional areas of the existing species while the ruled lines indicate the larger areas over which *Diospyros* extended its range during its geological history. This range was probably more extensive even than is indicated since data are not available for plotting the complete record which will always remain more or less incomplete.

BOOKS AND CURRENT LITERATURE

Plant Physiology: with Reference to Plant Production.—Professor B. M. Duggar's book has a descriptive and suggestive title[1] which, in this day of courses in agriculture even in the schools (especially city schools?), should give it a prompt sale. What is of equal, if theoretical, importance is that the book deserves a good sale, for it is an interesting presentation of the main facts of plant physiology by a man of such training, experience and present interests that he can see the subject in its relations to other subjects as a pure physiologist probably cannot. The book is interesting also as an evidence of the appreciation, by those not physiologists of the value of plant physiology in "practical" life. It has often been said that *any* study of plants will and must aid the agriculturist. A moment's reflection will show that this is not true; and it must be admitted that the use of most of the physiologist's store of facts is hidden in the future. The beneficial results of the study of botany by students in the agricultural colleges—and it is especially for these that the book is written—are of two sorts: first, the acquisition of a knowledge of plants which they can themselves apply to their own satisfaction, both as pleasure and as profit; and second, a realisation that, at times, general knowledge should be supplemented by special, as when a man calls upon an oculist instead of his family physician or of prescribing for himself. No one can lay down this book with the feeling that he knows the whole subject, for Professor Duggar takes pains to avoid sweeping general statements and to point out the limits of our knowledge. These limits, however, are spoken of not as barriers but as problems.

The various topics of plant physiology are presented in somewhat unusual perspective. For example, the devotion of only thirteen pages to growth movements is in marked contrast to the books of thirty years ago (or even less), in which growth movements were described at great length, with scarcely an idea as to their mechanism and meanings. Perhaps thirty pages devoted to variation (which is real and recognizable) and heredity (an abstraction of which less and less is known as studies

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[1] Duggar, B. M., Plant Physiology, with Special Reference to Plant Production. Pp. 516, figs. 144; New York, The Macmillan Company, 1911 ($1.60).

become more exact) may be too large a share of the space. The other chapters show how hazardous physiological writing is for those who are chemists but not physicists, or vice versa, or worst of all, neither! The plant physicist may complain of the chapters dealing with absorption and transfer, the plant chemist will wish for less sanguine and more exact statements regarding food-materials, food manufacture and use; but on the whole the book is good, a welcome attempt to aid agriculture by abstract knowledge and to broaden and enliven physiology with the idea of usefulness.—G. J. P.

NOTES AND COMMENT

Dr. M. Rikli, of Zurich, has contributed to Fortschritte der Naturwissenschaftlichen Forschung a paper entitled Richtlinien der Pflanzengeographie, which is at once an historical sketch of the progress of Plant Geography and an estimation of its present activities. Three subdivisions of Plant Geography are recognized: the Floristic, the Ecological and the Genetic. The operation of various environmental factors is discussed in a general way at considerable length, and some recent forms of instruments are described, particularly in actinometry. The habitat is discussed and also the rôle of the individual species in Plant Geographical work. Rikli considers the chief function of Ecological Plant Geography to be the study "of the relations between external and internal factors, which together are of first importance in determining the distribution of individual species." Very timely and important is the emphasis here and throughout his paper on the individual species of plants. Ecological Plant Geography has now been concerned for a number of years in the study of plant associations, chiefly by means of observational methods, partially by means of methods which have been designed to give observation greater exactness, and partly by means of intensive study of environic factors. As the problems attacked by Ecological Plant Geography become less general and more specifically directed to the relation between the "exogene" and "endogene" factors of Rikli, the more will its activities be drawn away from the association and toward the individual plant. Nevertheless, as Rikli points out at the conclusion of his paper, Genetic Plant Geography has much to contribute to the problems of environic factors and their effects.

At the same time that Professor Weiss, in his vice-presidential address before the botanical section of the British Association at Portsmouth, is remarking on the untenability of the view that the xeromorphy of the plants of the Carboniferous period may be due to their actually being halophytes, Dr. Dachnowski is making a suggestion which is far more plausible. In a paper in The American Journal of Science (July, 1911) entitled The Problem of Xeromorphy in the Vegetation of the Carboniferous Period he summarises the work by himself and others on the toxic properties of bog water, and develops the view that the xerophilous character of Carboniferous forms may be attributable to similar conditions of toxicity in the substratum occupied by the plants of that epoch.

THE SUCCESSIONS OF VEGETATION IN OHIO LAKES AND PEAT DEPOSITS[1]

A Preliminary Report

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The report here outlined was presented at the Minneapolis meeting of the American Association for the Advancement of Science (1910). The survey of the vegetation was undertaken for the Geological Survey of Ohio during the past two years. As a result of investigations carried on in the laboratory certain correlations have been determined between the different types of vegetation and the available water content of the soil occupied by each type. Other factors enter into the correlation but the data in hand permit the tentative generalization that the relation between the available water content and the respective quantity required by plants is the chief limiting factor.

The present distribution of the types of vegetation frequenting lakes and peat areas renders necessary the recognition of the geologic and physiographic features which originally determined the sources of the Ohio flora. A detailed account of the geology, soil, and topography of the state is given in a bulletin soon to be issued dealing with the peat deposits of Ohio. No attempt will be made to meet that want in this short paper. Ohio may be divided into four physiographic regions, which in their climatic conditions follow closely the divisions given by the U. S. Weather Service. They have been named as follows: (1) The Lake region; (2) the Western Morainic Plain or Calcareous region; (3) the Scioto Valley region; (4) the Appalachian region. These physiographic regions have a special interest and significance both as

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[1] Contribution from the Botanical Laboratory, No. 65.

related to the system of degradation processes which has given character to Ohio topography, and as to the highways of dispersal from centers of plant distribution, the continuity of dispersal and of environment, and the divergence and degree of individual variability of plants in structure and function with departure from localized foci of dispersal. Glacial influences obliterated the older system of surface drainage which was northward across the state; the new drainage now marked by streams flowing in the opposite direction, is still in an undeveloped stage, and the plant and animal life of today is still in the process of northward dispersal.

Along a line of elevation which separates the waters of the Ohio River from those of Lake Erie are striking instances of peat-depositing water basins and finger lakes. Many of the larger glacial lakes have long since become filled with peat.

Since the postglacial migration of plants the following major successions of vegetation have led to the establishment of the existing flora on peat depositing lakes, and in shaping the particular associations: (1) Open water succession; (2) Marginal succession; (3) Shore succession; (4) Bog succession; (5) Mesophytic succession. There are a number of secondary successions which have been brought about by the destruction (fires, drainage), and removal (cultivation) of the original vegetation. As here listed this sequence of groups indicates the structural and historical relationships. The more genetically related groups and their associations were formerly not isolated from one another by any considerable space; they occupied the region more continuously than found today.

The first three groups are members of a related series in a larger vegetation type—the hydrophytic formation. It culminates in a stable association so far as the free water is concerned. The fourth group is pronouncedly xeropytic in response to physiological drouth conditions. The members resemble in many points of form and structure the vegetation of rainless regions and bare rock surfaces,—representative types of the xerophytic formation. With the complete filling of the water basin the accumulation of vegetable débris above the water level tends to an increase in the oxygen supply, in available water, and a change in the character of soil organisms and their reactions. The vegetation passes to the mesophytic type of plant formations, which may be regarded as the culminating succession in the progressive series occurring on the same habitat under present climatic conditions.

It is an intricate task to discover a guiding principle and to arrange an otherwise confusing diversity into a genetic and dynamic system. But the recognition that the nature of a lake and bog environment is constantly selective, and that associations of plants succeeding one another are each characterized by a definite physiognomy in response to their dependence upon the supply of available water under environmental conditions essentially similar otherwise, renders this classification more significant.

In separating associations only such have been indicated for each succession as were recognized with sufficient clearness to be the controlling vegetation in a habitat comprising elements of stability in the sum of habitat life-relations.

I. OPEN WATER SUCCESSION

1. *Plankton associations.* Water basins begin with the plankton association. Bacteria, diatoms, single-celled algae and various other forms are the organisms floating in the open water of lakes and partly filled peat bogs. In vertical range they are confined largely to the surface of the water. Saprophytic forms occur at the bottom. The correlations of light, temperature and aëration with distribution, vertical zonation, and seasonal changes in quantity and quality of organisms, and the process of "self-purification" of shallow areas need further investigation.

II. MARGINAL SUCCESSION

1. *Submerged associations.* In lakes overlying the limestone area of the western half of Ohio *Chara* takes a prominent place. Where *Chara* is not present there is but little change from the innermost microphytic region to the belt of submerged plants nearer the margin. Almost all lakes and peat-depositing water

basins have a zone of submerged vegetation with more or less distinct alternation and layering. Ordinarily *Ceratophyllum demersum* comprises the main part of the association in abundance of individuals. *Potamogeton* species (*P. pectinatus, P. lucens, P. natans*) are next in importance as principal and dominant species. There is great variation in the number of species and the order of their importance; no attempt is made here to give a complete list. Upon decay the finer detritus reaches the deeper and remoter parts of the lake bottom, filling it with a soft oozy mud. Nearer the margin the débris is often greenish and distinctly laminated.

2. Semi-aquatic or amphibious associations. The predominating species are the white and yellow water lilies (*Castalia tuberosa, Nymphaea advena*) and the knotweeds (*Polygonum muhlenbergii, P. hydropiperoides, P. amphibium*). There is no sharp limit between the several associations and those preceding and following them, hence the individual zones contain species of secondary importance in great variety.

3. Floating association. Some of the constant representatives are the duckweeds (*Lemna minor, L. trisulca, Spirodela polyrhiza*), liverworts, and mats of algae. They occur among the members of the semi-aquatic associations. Clearly defined societies do not exist in this association as the plants are easily transported by wind and currents. The association corresponds in point of vertical zonation to the ground layer in forests, but light does not constitute the controlling factor. In sheltered and enclosed pools, where the decay of the plant débris is incomplete, there is noticeable in the duckweeds a difference in root production, in amount of frond, and in rate of reproduction. This condition indicates a growing season that is shortened by the limitation of the available water supply and by struggles with the reactions exerted upon the habitat by each stage of the vegetation cycle.

III. SHORE SUCCESSION

The plants that follow as the filling-in of the water basin continues, are either pioneers of the land vegetation or of the bog according to the nature of the determining soil process. A few members are in a sense transitional and can assume an aquatic or terrestrial habit. Up to this stage in the process the marginal and shore plants still may receive better aëration and sanitation on account of the more frequent stirrings by waves and surface current action. The physico-chemical and biological conditions of the substratum are yet favorable for rapid growth, and any gaseous or other injurious products due to partial decomposition of the débris are in dilutions not to inhibit functional activity of many plants. In fact their presence in small quantities carries with it a corresponding intensification in the growth rate of some species. Nevertheless, it is interesting to note that a number of the components of this succession show striking devices such as aerenchyma, internal air-containing spaces, respiratory roots and lenticels to secure sanitation. The following associations are the most typical in furnishing the transition to a bog succession.

1. Decodon verticillatus association. The botanical structure of the association is best described as follows: Facies or predominating species *Decodon verticillatus*, frequently accompanied by *Typha latifolia* and *T. angustifolia* as principal species. Among the secondary species are *Radicula aquatica, Cardamine bulbosa, Cicuta bulbifera, Sparganium eurycarpum, Sagittaria* sp. Several minor societies are seasonal aspects; they are determined by such species as *Hibiscus moscheutos, Bidens trichosperma, Rumex* sp., *Solanum dulcamara* and others.

2. Carex-Juncus-Scirpus association. In only a few lake and peat deposits are the important forerunners and mat formers species of sedge (*Carex filiformis, C. interior, C. comosa*). With them are found occasionally *Juncus acuminatus, J. tenuis, Carex lurida.* Among the plants which share the habitat of the sedges is *Calla palustris* in the bogs of northeastern Ohio. In a few inland lakes and especially along the shore of Lake Erie *Scirpus validus* and *S. americanus* are the forerunners of a pure marsh.

3. Typha association. There are numerous tracts in which the cat-tails are the most conspicuous plants. They give but little opportunity for the growth of secondary species. *Poly-*

gonum sagittatum, Impatiens pallida, Sagittaria sp., and *Aspidium thelypteris* are the representative undergrowth.

4. Calamagrostis canadensis association. This type of shore succession, with *Phragmites communis* on drier parts as a principal component, occupies comparatively large areas in counties along the divide. *Cladium mariscoides, Aspidium thelypteris, Hypericum virginicum* and *Onoclea sensibilis* are listed here to give a better idea of the composition and general appearance of this association. The condition of unstable equilibrium which exists is more favorable for *Calamagrostis* during wet years and more favorable for *Phragmites* during dry years.

5. Phragmites communis association. It occurs more typically along the shores of Lake Erie, between the bar sections and the mainland, where it is preceded by *Scirpus validus* and *S. americanus,* and *Zizania aquatica.* In the earlier stages of development the association includes, as in inland localities, *Typha* sp.; *Sparganium eurycarpum, Sagittaria heterophylla* and others form a secondary layer, alternating and mingling with *Carex comosa, C. aquatilis, Juncus canadensis.* The *Phragmites* association often succeeds a bog meadow (cranberry-sphagum association) in localities where the peat is grounded solid and well drained.

These various types of associations in the shore succession are often to be seen along the shore of one lake. Correlations with soil conditions are more easily established than with any other one factor. Differences in light and evaporation affect the plants less critically as yet. Competition becomes intenser in the later stages of the succession. Of the several types the *Phragmites* association indicates the better physical condition of the soil, favorable also for agricultural purposes.

IV. THE BOG SUCCESSION

Without change of climate or of mineral salt constituents, the aquatic and marsh vegetation becomes suppressed under certain conditions. Organic processes in the substratum, as they approach the limit of favorable conditions, become of greater importance than variations in light, temperature or evaporation.

They induce the establishment of the intermediate stage, the xerophytic formation. Frequently one or more phases of the bog succession are omitted entirely, and various deviations or intercalations occur; always, however, they are replacing one another quite independently of climatic and topographic changes. The succession of associations, like that of the displacement of successions themselves, is a form of edaphic selection due to the establishment of certain species and the exclusion of others. The plants themselves are the most important factor in bringing about the change. As the production of land by the activity of the vegetation continues, concomitant with the organic changes in the soil is the replacement of one type of vegetation by another.

A. The bog meadow associations

According to the preponderance of certain plant forms, two types of bog meadows may be recognized:

1. Vaccinium macrocarpon-Spagnum sp. *association.* The vegetation is diversified and rich in the variety of possible facies and societies. The list of a fairly representative example of a bog meadow would include *Carex limosa, C. filiformis, Menyanthes trifoliata, Rynchospora alba, Dulichium arundinaceum, Potentilla palustris, Eriophorum virginicum, Drosera rotundifolia, Sarracenia purpurea* and less frequently *Scheuchzeria palustris.* In addition to this groundwork of plants are several species of orchids, *Scirpus, Juncus, Aster* and various stragglers from preceding associations and a number of invading migrants. *Parnassus caroliniana, Lobelia spicata, L. syphilitica, Chelone glabra, Gentiana crinita, Campanula aparinoides* are less common.

The amount of mineral salts is of subordinate significance. Lime in the soil does not prevent their growth, for cranberry-sphagnum meadows were until recently extensive in counties overlying the Niagara and Monroe limestone formations, and on peaty substrata near springs the water of which is charged with carbonate of lime.

The type of peat is coarse in texture and conducts water readily. With any alteration in the water level the mat of the cranberry-sphagnum bog is able to shrink or float. Variations in the position of the water table do not influence the association so greatly as is often stated, nor do they offer an explanation of the xerophytic structure of the plants. On Cranberry Island (Bot. Gaz., 52) bog xerophytes succeed hydrophytes upon a habitat with a prevailingly high water level. Variations in the water-table due to various causes range at times between 4 and 7 feet (1.2 mm. to 2.1 mm.), but they do not affect the association since the mat is floating.

The evaporating power of the air is not such as to approach the limit of favorable conditions. The average rate of evaporation is about 10.9 cc. daily as compared with 8.1 cc. for a forested (Maple-Alder) zone, and 15.8 cc. for an open lawn on the university campus. The data plotted as graphs exhibit a great similarity in the general course, and show coincident and proportionate minima (7.6 cc., 3.9 cc., 12.6 cc. respectively for each station as mentioned) in early June, and maxima (17 cc., 11 cc., 21.5 cc.) in late July. The data indicate that the rate of evaporation in the bog meadow is not a sufficient cause for the xerophytic character of the vegetation; nor are the differences in the rates efficient factors in causing successions.

In this association the growing season is determined not by the length of period of suitable soil temperature but by the length of the period when the available water is physiologically sufficient to maintain growth. Ability to resist toxicity is essential to the successful growth of the plants in this environment. Winter temperatures below 32° F. at the one-foot level have not been found to occur in a bog meadow of Central Ohio.

Acidity in the soil varies from less than 0.00075 to 0.004 but can not be associated with the injurious substances accumulating through bacterial action and otherwise in the peaty substratum (*l. c.*)

2. Carex-Juncus association. The second type of bog meadow is produced principally by sedges (see *Carex-Juncus* association p. 29). The association includes many of the species of the cranberry-sphagnum bog meadow but in numbers rarely above a third of that of the sedges. The sedge bog meadow is characteristic of flat areas and along shallow shores. The type of peat is firm, finely fibrous and felt-like in appearance. It retards drainage, and in rainy seasons retards the run-off. As the water level becomes continuously raised with the accumulation of the dominant growth, a peat bed is built up from the bottom of the successive elevations of the water level. Since these conditions eliminate many species of hydrophytic plants, the peat is usually homogeneous in texture. The flora of a deposit of that character becomes heterogeneous only when the water level remains high or low for a long time. Sedge bogs are relatively rare and no longer typical in Ohio.

B. The bog heath associations

No matter how numerous the seeds or fruits brought in by wind, birds, or other agencies, effective establishment is possible only to the few plants in which there is some sort of correspondence or balance in plasticity of function or in habitat form to the life-relations in the peat substratum. The soil processes are best expressed in terms of reduction action. The pioneer invaders are at first isolated, but mass invasion is not infrequent upon transition areas and tension lines. The distribution of bog heaths is, however, far more limited than that of any other of the associations in the cycle. This is largely due to the greater specialization in habitat requirements. Other plants are excluded for the reason that they can not subsist on the organic compounds arising in the substratum.

1. Chamaedaphne calyculata association. With few exceptions the association is limited to and more typical in the northeastern portions of Ohio. The botanical composition of the vegetation structure is relatively uniform; *Chamaedaphne calyculata* in low but dense and almost impassable thickets, with *Andromeda polifolia* and *Gaylussacia baccata* as principal species. Several ferns (*Osmunda cinnamomea, O. regalis*) and *Rubus setosus* are frequent where the cover is scattered and more open. The ground layer consists of sphagnums and polytrichum overgrown with *Rubus hispidus*.

2. Potentilla fruticosa association. This type of bog heath occurs more typically over limestone regions *Potentilla* predominates, but *Aspidium thelypteris* often occurs in dense mats in the interspaces. It is accompanied by scattered plants of *Andromeda glaucophylla, Betula pumila, Lobelia kalmii,* and several golden rods.

3. Gaylussacia baccata-Vaccinium canadense association. This association has few secondary species and varies but little from season to season. It never becomes very abundant and hence represents the least stable type of heath associations.

The reactions of the heath succession cannot be entirely unsuitable, for the soil, though sterile to most plants, is undergoing changes which enable the taller shrubs to secure a foothold. The scanty but efficient leaf-fall permits an accumulation of raw humus above the water-table. This brings the humus level within the reach of aëration and weathering. Partial occupation by shrubs ensues and later their complete establishment.

C. Bog shrub associations

1. Alnus sp.-*Rhus vernix association.* This is the most general and constant component of the bog flora of Ohio at this stage. *Alnus incana, A. rugosa,* and *Rhus vernix* are the facies with *Aronia nigra, A. arbutifolia, Vaccinium corymbosum, Ilex verticillata,* and *Nemopanthes mucronata* as principal species. The secondary species are mainly from adjoining associations. There is a tendency toward the segregation of *Vaccinium corymbosum.* It is more vigorous at the outer border.

2. Salix sp.-*Populus tremuloides association.* It is only on shallow peat in which the percentage of mineral matter is high and on shoreward places bordering a grassy marsh that the *Decodon-Typha* association is followed by willows with button-bush and dogwood without the occurrence of an intervening bog meadow and typical *Alnus-Rhus* association. Of the willows *Salix pedicellaris, S. Candida* and *S. lucida* form an integral but small part of the present bog vegetation.

3. Cephalanthus occidentalis-Cornus sp. *association.* The more open the vegetation the greater the tendency to vary and the greater the number of species of secondary importance. The association is found in a variety of physiographic situations. Its characteristic principal species are *Cornus stolonifera, C. paniculata, C. amomum, Rosa carolina* and several willows (*Salix cordata, S. nigra, S. discolor*). Seasonal aspects are prominent.

The last two associations contain members more southern in distribution than northern. The association which follows more directly is not the bog forest but the *Acer-Ulmus* association. The presence of an undergrowth which belongs to the southern deciduous forest center indicates conditions favorable to a rapid final establishment of deciduous trees.

D. The bog forest associations

The replacement of a bog shrub association may occur without the intervention of any factors other than the appearance of the invading forest species. Two well-marked types of bog forest associations are easily distinguished.

1. Larix laricina association. Tamarack bogs of various stages in development are found in Ohio. There are localities with the association of conifers just developing at the margin of bog heaths and shrubs; in others the conifers have completely covered the filled-in peat basin ("muskeags"), and are now disappearing as an association. Scattered individuals of *Pinus strobus, Tsuga canadensis* and *Betula lutea* are present, with shrubs derived mainly from the *Alnus-Rhus* association. *Rhododendron viscosum* is found in several localities. *Taxus canadensis, Medeola virginiana, Clintonia borealis, Dalibarda repens* and *Lycopodium* sp. occur apparently only in northeastern localities.

2. Thuja occidentalis association. This type of conifer dominance in bogs is well exemplified in a bog about thirty-five miles west of Columbus (Ohio Naturalist, 9:193–199. 1910). The vegetation in open stands is now found varying in the direction to the deciduous forest. With arbor vitae are found *Acer rubrum, Liriodendron tulipifera, Fraxinus nigra, Juglans cinerea, Platanus occidentalis* and *Prunus serotina.* The undergrowth is mainly that of the *Alnus-Rhus* association.

V. THE MESOPHYTIC FOREST SUCCESSION

As the soil processes migrate toward the center of a filled-in basin, and the bog conditions become eliminated, the advance of the bog associations continues toward the center also. The direction and rate of the movement varies but little from the slow progressive changes in the substratum. In some deposits the depth to the mineral subsoil is greater than 30 feet (9 m.), but the deficiency in mineral substances, such as lime, potash, phosphoric acid, etc., does not render it difficult or impossible for trees to grow luxuriantly. The deciduous forest association arises in part by the varying relation between trees, light and evaporation. The reaction of the deciduous invaders consists mainly in the addition of leaf humus and assimilable organic compounds. It would seem on account of the great difficulty experienced in extracting the water held in peat by any means except high temperature, that the lower water-table would determine the succeeding association to be the most xerophytic, and that any tendency to excessive transpiration accompanied by slow absorption from the soil would lead to more highly developed protective features against the loss of water. However, with the descent of the ground water follows a more thorough decomposition and oxidation of injurious organic matter. The layer of humus is now kept wet by the upward movement of water. Facility of percolation, power of raising water, all of which are greatest in peat, assume an importance increasingly favorable to the incoming vegetation, and to the action of fungi and mycorrhiza. The gradual invasion of deciduous trees and the replacement of conifers eventually leads to the complete extinction of bog conditions, to stability and the permanent occupation of the habitat by an association here characterized as the climatic unit of Ohio forests—the predominance of maples, ash, oak, elm, walnut and others.

1. Acer-Fraxinus-Ulmus association. Several of the tamarack bogs of northwestern Ohio have a peat soil, the conditions of which favor a number of deciduous trees. Among the species that succeed best are in addition to *Acer rubrum*, *Ulmus fulva*, *U. americana, Liriodendron tulipifera, Juglans nigra, Carya cordiformis. Rhododendron viscosum* is still an occasional constituent in the shrub layer beneath the trees.

Elms, black ash, the tulip tree, and black gum (*Nyssa sylvatica*) are frequent members of tamarack bogs in several localities of northeastern Ohio.

In a few bogs of central Ohio the tulip tree, *Magnolia acuminata, Celtis occidentalis, Amelanchier canadensis* are found mingling with the northern components. They are typical examples of an incoming forest association, the species of which attain their best development farther south.

SECONDARY SUCCESSIONS

The successions due to the intervention of man show that the structure initiated after fire and clearing consists of pioneers derived to a large extent from the original associations. They re-establish themselves in a much shorter time on soils in which the physical conditions approach those of the bog meadow and bog shrub. Breaking done on peat soil occupied by bog forests or mesophytic forest species will result in the establishment of a vegetation characteristic of mineral soils. The botanical structure is chiefly made up by ruderal invaders, capable of rapid mobility and establishment; the chance for the usual sequence of successions then becomes remote. Fungus diseases are of minor importance in modifying the vegetation cover. Reverse courses of development, retardation, or the hastening in the sequence of successions often occur when for any reason drainage, drought, shrinkage of the peat soil, or excessive precipitation produce variations in the available water. Bogs of that character present a disjointed distribution and a confusing diversity.

THE RELATION OF VEGETATION TO THE CHEMICAL NATURE OF PEAT SOILS

This problem has been the subject of a long standing dispute. Not all field work is adapted to throw light on this vexed question. Difficult as is the attempt to establish a correlation between vegetation and any one factor of the environment, yet it is possible to make such a correlation within the area here investigated, where there is a certain uniformity in regard to the chemical character of the soil. An analysis of Ohio peat shows the following range in chemical composition:

Chemical Analysis of Ohio Peat

	ASH	NITROGEN	POTASH (K_2O)	PHOSPHORIC ACID (P_2O_3)	LIME (CaO)
Minimum	3.65	1.01	0.10	0.03	
Maximum	25.44	3.48	0.98	0.50	4.52

It would be interesting to determine the percentage of ash in the herbs and shrubs, and in the wood of such trees as form the principal covering of a peaty basin. The analyses reported by Sargent in the Ninth census of the forest trees of North America give the percentages for trees common to bogs. The data are interesting in showing that the majority of the trees frequenting bogs have a percentage of ash less than 0.50, and only a few of the deciduous species occurring on peat deposits have a percentage of ash greater than 1.00. The belief is widespread that the fertility of a soil may be judged from the study of the chemical character of the soil, and that soils markedly deficient in phosphates, potash, and other salts should be looked upon as barren and sterile. But comparisons of the vegetation of peat areas differing so widely in mineral constituents from land soils point to the fact that differences in mineral components are trifling as compared with the biological processes in the substratum and the differences in available water. There is little credence to be placed in the theory, as now held, of soil exhaustion, as any study or European conditions alone will show. Fuller knowledge of soil processes, of reduction action, sanitation, and available water will control the danger of soil deterioration more satisfactorily and economically.

The successions from the aquatic type to forests epitomize an ancient vegetation cycle. Elsewhere (American Journal of Science, 32:33–39, 1911) the writer has pointed out the probable ecology of fossil plants, in particular the physical conditions under which the plants of the coal-measure grew, and the succession of plant associations within the same ancient swamp area. The presence in the petrified débris, of fungi, mycorrhiza, woody pneumotophores (*Stigmaria*); the change in color of nodules taken from the bottom to the top of a seam, and the differences in the plant-remains, strongly suggest unfavorable conditions in the peaty substratum. It is not necessary, therefore, to postulate a moist tropical climate with vapors heavily charged with carbon dioxide.

ENZYME STUDIES OF LOWER FUNGI

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Recent investigations in the fields of bacteriology and mycology have led to many interesting observations. The intimate association of the lower forms of plant life with every-day phenomena is now just beginning to meet with the widespread recognition which it merits. Unfortunately, however, the attention of scientists has been confined for the most part to a study of the morphology and life history of these lower plants. Investigations of the subject from the chemist's point of view, though equally important, have not kept pace with the progress achieved in recent years by the bacteriologist and the mycologist. Yet many interesting disclosures of a chemical nature have been made by those investigators who realized the intimate relation between the life and growth of lower plants and the deep-seated chemical changes taking place in the surrounding medium.

One of the most interesting and important phases of phytochemistry is that which deals with the enzymes produced by plants. The study of plant enzymes in general is too comprehensive a subject to be discussed within the scope of this brief paper. The writer having been engaged for several years in the study of a particular group of fungi, which includes the more common saprophytic molds, it is to these that the reader's attention is directed. The molds included in this discussion comprise certain species intimately associated with some particular substratum, and cultures from these sources rarely require further identification. Thus the green mold of rotten apples, the blue and olive rots of citrus fruits, the green mold of Roquefort cheese and the gray mold of Camembert cheese are distinct species. Many related species are also widely distributed in nature but are not definitely associated with a particular substratum and their identification is not so simple a matter. Most of these molds readily adapt themselves to artificial cultivation, and for that reason the study of their enzymotic activities is much facilitated. The power of adaptation to artificial surroundings is so pronounced that a single definite crystalline substance may be supplied as the sole source of carbon or nitrogen in the nutritive medium, and the changes which it undergoes are therefore comparatively easy to follow.

The pioneer work of Pasteur in the domain of biochemistry led other investigators into the field and it was soon noted that saprophytic molds had the power of utilizing a number of definite chemical substances as sources of carbon and nitrogen. Since molds cannot utilize solar energy as do the higher plants, their metabolic activity is dependent upon exothermic chemical reactions which they institute in the culture medium. These reactions are, for the most part, of an oxidative nature. In the case of the more complex substances as proteins and polysaccharides, however, the substance must first be broken up into simpler compounds, and oxidation is therefore preceded by hydrolysis.

The formation of intermediary products by hydrolysis, whereby the original molecule combines with water and then splits into two simpler molecules at the point where the water enters, can be studied in the laboratory by comparatively simple methods. This type of reaction, corresponds exactly with the changes which the three great classes of food materials, the proteins, fats and carbohydrates, undergo in the alimentary tract of animals, preliminary to absorption. As in the case of the higher animals, so with these molds, the preparatory changes to which the complex food material is subjected are brought about through the agency of enzymes or digestive ferments. Since the activity of the enzymes, under suitable conditions, survives the death of the cell, the former can be made to manifest their activity in the absence of life. This is where a series of most interesting results has been obtained. The number and diversity of chemical substances which undergo hydrolysis when brought into contact with aqueous extracts from the dead mold cells is indeed surprising.

With our present limited state of knowledge regarding enzymes in general, we can only speculate as to what an enzyme is. Practically all we know thus far is that enzymes derived from certain sources manifest the power of inaugurating certain chemical reactions under definite conditions. According to the generally accepted view each type of hydrolysis is brought about by an enzyme which is specific for that substance or class of substances acted upon.

The enzymes which have thus far been demonstrated by the writer as present in these lower fungi may be seen from the following tabulation.[1]

DESIGNATION OF ENZYME	SUBSTANCE HYDROLYZED	PRODUCTS OF HYDROLYSIS
1. Protease	Casein	Amino acids
	Gelatin	Amino acids
	Peptone	Amino acids
2. Nuclease	Nucleic acid	Phosphoric acid, purine bases, etc.
3. Amidase	Urea	Ammonia, carbon dioxide
	Asparagin	Aspartic acid, ammonia
4. Lipase	Fats	Fatty acids, glycerol
	Esters	Fatty acids, alcohol
5. Emulsin	Amygdalin	Glucose, benzaldehyde Hydrocyanic acid
	Arbutin	Glucose, hydroquinone
6. Amylase	Starch	Dextrin, maltose
7. Inulase	Inulin	Levulose
8. Raffinase	Raffinose	Levulose, melibiose
9. Sucrase	Sucrose	Glucose, levulose
10. Maltase	Maltose	Glucose
11. Lactase	Lactose	Glucose, galactose
12. Histozyme	Hippuric acid	Benzoic acid, glycocoll
13. Catalase	Hydrogen peroxide	Water, oxygen
14. Phytase	Phytin	Inosite, phosphoric acid

Further investigation will no doubt reveal the presence of other so-called specific enzymes not included in this list. From the data at hand it appears that all these enzymes are formed, regardless of the chemical nature of the substratum that fur-

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[1] For a detailed discussion of methods employed the reader is referred to Bureau of Animal Industry Bulletin No. 120 and subsequent publications by the writer.

nishes the food material for the mold. If these various manifestations of enzymotic activity are to be regarded as due to individual specific enzymes, it must be assumed that each enzyme performs some specific function in the nutrition of the fungus. But it is difficult to understand why a long category of enzymes should be produced in the absence of their specific substrata. The argument that these enzymes were developed during past generations when their presence may have been requisite and that they now represent inherited characters that were acquired under special conditions in the previous history of the species is scarcely valid, in view of the extreme improbability of certain of these substrata ever having served as nutrient material. At any rate it is inconceivable that a substance like hippuric acid could have been presented as food material through a sufficient number of generations for the mold to adapt itself permanently by the secretion of an enzyme for that purpose, since experiments in which attempts have been made to develop enzymes that are known to be wanting have so far resulted in failure.[2] Again it may be argued that the function of these enzymes is to assist in building up or synthesizing the various complex cell components, since enzyme action is known to be reversible. This is undoubtedly true to some extent, but the presence of an enzyme like raffinase is still unaccounted for.

From the data obtained by the study of fungus enzymes there is much to argue against our present conceptions of the specificity of enzymes. Very few, if any, really "specific" enzymes are known, and the assumption that the hydrolysis of different substrata by one and the same preparation is due to the presence of several enzymes has little experimental evidence in its support. The "side chain theory" by which the various manifestations are explained as due to specific groups or atom complexes contained in some gigantic enzyme molecule is just as difficult of application to the case in hand. It seems more than likely that some time in the future we shall have to readjust our conception of the specificity of enzymes.

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[2] The enzyme "tannase," recently studied by Knudsen, is apparently an exception, since its presence is determined by the presence of tannin in the culture medium.

BOOKS AND CURRENT LITERATURE

Root Habits of Desert Plants. In a recent publication[1] by Dr. W. A. Cannon we have a highly interesting as well as exhaustive consideration of the root habits of a variety of desert plants. After a preliminary treatment of the moisture and temperature conditions of the soil in the region around Tucson, Arizona, the author enters into a discussion and description of the root systems of upwards of sixty species which are characteristic of that locality. They are considered under three heads as follows: summer annuals, winter annuals and perennials. Among the annuals there is a striking difference between those which flourish during the summer rains and those whose growing season is during the time of winter precipitation, although both have about the same depth of penetration of the roots. Characteristic of the latter are the prominently developed tap roots with only a relatively small development of laterals, while the former have a much more generalized type of root system. In the summer annuals the laterals are well developed and the main root itself is frequently forked, affording thereby a greater absorbing surface than is found in the winter forms.

As a working hypothesis to explain these conditions the following is suggested. In the summer the conditions, both sub-aerial and subterranean are suitable for rapid growth and, the most favorable conditions for water absorption being offered, there is the resultant development of the root system. In the winter, on the other hand, the soil, to an appreciable depth, is cooler than the air in the day time, thus retarding root development. As a result the growth of the shoot is limited, and this in turn demands less of the roots. In the opinion of the author it seems to be the relative difference between air and soil temperatures in winter and in summer which is to be regarded as the critical factor. In summing up the question he states that it may be said that the summer type of root system tends towards hygrophily, while that of the winter annual has a rather xerophilous inclination. Such of the winter annuals as have a more generalized root system, and there are a few, are limited to regions where the soil conditions are especially favorable.

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[1] Cannon, W. A., Root Habits of Desert Plants. Carn. Inst. Wash., Publ. 131, 1911.

In the study of the perennial root systems the plants were examined *in situ* and the excavated roots carefully mapped. Among the plates there are a number of these root system surveys represented and they are, perhaps, the most striking of any of the features of this interesting paper. The perennials studied comprised a number of the larger cactus forms as well as other types, such as ocotillo, creosote bush, yucca and so forth. The root systems of these perennials are summed up under three heads, a generalized type and two other categories, one of which has a prominent tap root and the other prominent laterals. One of the notable facts brought forward in the paper is the great diversity in the extent and position of the roots of these desert perennials. Far from having, as a rule, deeply penetrating roots of great length, many have exceedingly shallow roots, notably the barrel cactus, the roots of which are so close to the surface as not infrequently to be exposed by the erosion of rain storms. In fact it appears that among the cacti the extremely long shallow laterals form the absorbing system and the relatively short tap root and in some cases the modified bases of the laterals constitute the anchoring apparatus of the plant. The deeper root systems of the more generalized type were not found in the plants growing on the detrital slopes, but rather in those which inhabit the flood-plains and washes. Thus the mesquite was found to penetrate to the depth of 5 meters in the flood plain of the Santa Cruz where it grows to the best advantage and the author is inclined to doubt if the smaller, stunted bush-like trees of this plant which grow at slightly greater elevations from the river, ever reach the water table with their roots. The ability of some of the perennials to form seasonal, deciduous roots during the rainy seasons must be of no small importance.

In the matter of competition among individuals for water supply the plottings of root systems, previously referred to, are of especial interest. On the slopes, among plants of the same species, the competition is often of the keenest, as is shown strikingly in one of the maps illustrating the distribution of the roots of a creosote bush (*Covillea tridentata*). Among the cacti there does not appear to be so sharp a rivalry.

There are many other facts of interest to which it is impossible to call attention within the limits of a review. The results in general modify in no small measure our previous conceptions of root distribution in desert plants and well illustrate how an extended study of diverse plant forms is apt to modify generalizations either drawn from relatively few instances or argued on teleological grounds.—H. M. R.

NOTES AND COMMENT

The summer of 1911 will remain noted in the annals of Plant Geography by reason of an excursion through the British Isles under the able guidance of the British Vegetation Committee, an organization of enthusiastic plant geographers who are systematically studying the vegetation of Great Britain and Ireland. The history of this excursion very properly goes back two years to an expedition conducted through Switzerland by Professor Schröter of Zurich, the great Swiss plant geographer and prince of excursion leaders. On that occasion there were several foreign guests, among whom was Dr. Tansley of Cambridge, who was thus inspired to plan the great international excursion of 1911, with the able assistance of Dr. Moss and other colleagues of the Vegetation Committee.

The party which assembled at Cambridge, August 1, was truly international, consisting of Professor Schröter and Dr. Rübel of Zurich, Professor Drude of Dresden, Professor Massart of Brussels, Dr. Ostenfeld of Copenhagen, Dr. Lindman of Stockholm, Professor and Mrs. Clements of Minneapolis and the writer and his wife of Chicago. A few days later we were joined by Dr. Graebner of Berlin. The party was accompanied throughout the tour by the leader of the excursion, Dr. Tansley of Cambridge, and by Dr. Druce of Oxford, the well-known specialist on the British flora. A varying number of British botanists were with us at the points visited.

The inauguration of the excursion at Cambridge was most delightful; shortly after the gathering at the Botany School, there came a luncheon at Emmanuel College and a ramble through the college grounds. The first afternoon was devoted to the Botanic Garden, where the party were the guests of Mr. Lynch, the director, and his wife. The second day was given to a study of the aquatic vegetation of the Cam under the guidance of Dr. Moss, terminating in luncheon at the home of Dr. and Mrs. Tansley in Grantchester. That evening the gentlemen of the party were entertained at dinner in St. John's College by Professor Seward and Dr. Blackman, and the ladies were entertained by Mrs. Seward at her home.

As an index that strenuous field work, rather than a succession of luncheons and banquets, was to be the chief order of the trip, the third day was initiated by rising at 5 o'clock and starting off by train for the Norfolk Broads, where three delightful days were spend under the guidance of Miss Pallis in studying the rich aquatic, marsh, and fen flora of that region. These days alone sufficed to show that the British Isles, in spite of their great density of population, have large areas of natural vegetation admirably adapted for intensive study.

A day was spent at Blakeney, Norfolk, under the masterly leadership of Professor Oliver. We studied there the intensely interesting salt marshes and gravel dunes which have proven so rich in problems that Professor Oliver has established at this point at seaside laboratory for their study. Three days were spent about Manchester, one in the famous Derbyshire dales, where Dr. Moss enthusiastically demonstrated retrogressive succession in the limestone forests. Two days were spent under the leadership of Professor Weiss and Dr. Woodhead on the mountain moors, which exhibited, at least to the American guests, an entirely new type of vegetation, not alone in its composition, but also in the astonishing evidences of retrogression. This part of the trip will be remembered also for two delightful dinners, one at Manchester, where the hosts were Professor and Mrs. Weiss and Dr. Lang, the other at Huddersfield, where the Cave Club acted as our host. Space forbids even the mention of most of the numerous kind friends who served as hosts at luncheons and teas during the progress of the excursion.

The dunes at Southport, to which a day was devoted under the guidance of Professor Weiss, proved to be of great interest. In northwestern England the leaders were Dr. Rankin and Dr. Lewis, and there we became well acquainted with lowland moors (cross sections being found to aid in elucidating their problems) and also with the mountain moorland of Cross Fell.

The several days devoted to Scotland were packed full of interest. In the Scottish field trips our efficient guide was Dr. Smith, assisted by Dr. Crompton, who interpreted the geology and physiography. At Edinburgh we explored the Botanical Garden and were most royally entertained at dinner by Professor and Mrs. Balfour. The forests of Dunkeld, the interesting and floristically rich alpine vegetation of Ben Lawers (where Professor Balfour was the leader), and the lovely scenery of the Trossachs appealed equally to the scientific and to the esthetic sense. The sojourn in Scotland was fittingly terminated by a luncheon with Professor Bower and Dr. Lawson at Glasgow.

Nearly a week was spent in Ireland and this time was all too short. Our guide here was Mr. Lloyd Praeger, ably assisted by his wife. One can never forget the moors, heaths, and mountains about Clifden with their interesting American and Mediterranean floristic elements, Ballyvaghn with its peculiar limestone pavements, or Killarney with its botanical treasures set in the loveliest surroundings. The forests of Killarney have an almost tropical luxuriance, and the groves of Arbutus recall the counties far to the south. After a delightful afternoon in a private garden at Queenstown Junction, the party set sail for Plymouth. Two days were devoted to the heaths of southwestern England. The excursion proper was brought to a close by a dinner at Truro, given by the Royal Society of Cornwall.

The members of the excursion were guests of the British Association at the annual meeting in Portsmouth, and our final week, spent in company with the British botanists en masse, was a fitting climax to the month's tour of the islands. The chief features of the week included excursions to the yew woods, salt marshes, and heaths about Portsmouth; a symposium on the causes of the present distribution of the British flora; papers on various ecological and phytogeographical subjects and a botanical dinner.

As one of the foreign guests of the British botanists, I am sure that I express the feeling of all when I testify to a growing sense of heartfelt appreciation of the sumptuous treatment accorded us at every turn. It was an experience that will grow more fruitful with the years. The vegetation of the British Isles was even more interesting than we had thought would be the case, but the great result of the excursion was coming into close contact and understanding with each other. It is safe to say that the phytogeographers who met in England in 1911 now know one another, and will be able henceforth to understand and appreciate far better the writings from one another's pens. It was the universal testimony that these international excursions must thenceforth be a feature of phytogeography.—Henry C. Cowles.

SOME NOTEWORTHY NEW ZEALAND FERNS

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However little may be known generally regarding the flora and vegetation of New Zealand, there are few botanists but are aware that ferns occupy a prominent position in both, while many hold an exaggerated opinion as to the part this class of plants plays in the vegetation. In point of fact, however, with the exception in some places of extensive heaths of *Pteridium aquilinum* var. *esculentum*, the plant covering, in its broad features, is dominated by dark forest masses on the one hand, and, on the other, by brown steppe of tussock-grasses,[1] where ferns play a very subordinate part.

The 143 species of ferns, belonging to 38 genera, are, for the most part, members of the various rain-forest associations, where they occur in surprising abundance as plants of the lower and middle strata and as lianes and epiphytes. To a lesser degree various species are characteristic of special edaphic non-forest stations.

Ferns, all the world over, from their intrinsic beauty, the ease with which they can be dried, and their popularity for decorative purposes are perhaps better known than any other class of plants. The New Zealand fern flora is not backward in this regard, and no more "novelties" need be expected, so far as species go. But the treatment has been essentially floristic, and there is not a species but would afford interesting material for biological consideration, and which might be dealt with from various standpoints, even in the present limited state of knowledge. Here only a few ferns are briefly discussed which appear to supply material for consideration of more than mere local interest.

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[1] This applies only to primitive New Zealand. Many wide areas are now marked by green meadows and other artificial formations, and, so far as the plant covering, and even the flora go, might be a part of Europe.

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The living Osmundaceae, thanks to the brilliant work of Kidston and Gwynne-Vaughan,[2] stand out, at the present time, a conspicuous "link with the past," to use Professor Seward's apt term.[3] New Zealand can boast noteworthy representatives of both living and extinct genera, while the former grow under absolutely virgin surroundings, a matter of much moment when considering ancient geological climates and life conditions.

The living New Zealand genera *Todaea* and *Leptopteris,* though united by many pteridologists, belong to ecologically distinct classes, while systematically the former possesses large sori of many sporangia, and the latter small sori of few sporangia. Thus limited, *Todaea* consists merely of the one species *T. barbata* (L.) Moore. This fern is noteworthy, first of all, through its striking discontinuous distribution (South Africa, Eastern Australia, Tasmania, and New Zealand), a fact which can be most reasonably explained, as Christ[4] and Seward[5] both agree, on the supposition that it must have been at one time more widely spread in the southern circumpolar region. Further, in New Zealand it is restricted to the extreme north, hardly extending beyond latitude 35° 20′ south,[6] although it can certainly live quite well south of that limit so far as climatic and edaphic conditions go. In fact it is in the position of a species disappearing before our very eyes, for a slight increase in the number of rainy days, or a general sinking of the land surface would cause its gradual extinction. Nor is such a happening at all unlikely, since the extreme north of Auckland has undergone many changes in level, and vast kauri (*Agathis australis*) forests, as evidenced by extensive deposits of fossil resin, occupied land now dune, heath, swamp, and bog.[7]

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[2] Gwynne-Vaughan, D. T., On the fossil *Osmundaceae.* Trans. Roy. Soc. Edinb., 45, 46 and 47, 1907–1910.

[3] Seward, A. C., Links with the past in the plant world, Cambridge, 1911.

[4] Christ, H., Die Geographie der Farne, p. 154. Jena, 1910.

[5] *Op. cit.*, p. 78.

[6] Christ has unfortunately confused Auckland, the geographical district of the North Island of New Zealand, where *T. barbata* occurs, with Auckland Island, one of the New Zealand Subantarctic Islands in latitude 50° 20′ south, an easy enough mistake, though he is quite right in assigning another tree-fern, *Hemitelia Smithii,* to that bleak and wind-swept spot (*op. cit.*, pp. 246, 247).

[7] Cheeseman, T. F., Trans. N. Z. Inst., 29: 337, 1897; Bell, J. M. and Clarke, E. deC., *Ibid.*, 42: 614–615, 1910.

To understand how forest conditions could be detrimental, the ecology of *T. barbata* must be briefly considered. So far as possessing a trunk is concerned it is a tree-fern, but, unlike most of its congeners, this trunk is not tall, slender, and crowned by a few fronds spreading umbrella like. On the contrary the trunk is short, massive, and, so far as New Zealand examples go,[8] not noticeable without a close examination, owing to the fronds being very numerous and crowded into a somewhat globular mass (see fig. 1). Such plants may be some 1.8 m. in diameter and 1.2 to 1.5 m. tall. The fronds put one closely in mind of *Osmunda regalis* L. They are 90 cm. long, more or less, the upper vertical, the lower semi-vertical, the stripe rather shorter than the blade and the pinnae bright or yellowish green, rather glossy, thick, coriaceous, opaque, and rather hard. The fern then is, at any rate, sub-xerophytic, and in consequence it never occurs in the forest but either grows mixed with *Leptospermum scoparium* Forst., a xerophytic shrub or small tree of ericoid form, or in open places in the *Leptospermum* heath exposed to the full sunshine and but little sheltered from wind. Between heath and forest an ecological contest is always in progress, xerophytic conditions favouring the former formation and mesophytic the latter.[9]

The fossil species *Osmundites Dunlopi* and *O. Gibbiana* were found in the extreme south of the South Island. *Osmundites Dunlopi* is considered by Kidston and Gwynne-Vaughan as related to *Todaea barbata*, and *O. Gibbiana* to the wide-spread *Osmunda regalis*.[10]

The two endemic New Zealand species of *Leptopteris*, *L. superba* and *L. hymenophylloides*, though so closely related to *Todaea*, demand absolutely different life conditions. Their fronds are of a true hymenophyllaceous character, being only a few cells thick and without stomata a true epidermis or intercellular spaces,

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[8] There is nothing approaching Australian examples with their trunks a ton and a half in weight. (See also remarks by Cheeseman in Manual of the New Zealand Flora, p. 1024, Wellington, 1906.)

[9] Cockayne, L., A botanical survey of the Waipoua Kauri Forest, pp. 30–31. Wellington, 1908.

[10] *Osmunda regalis* does not occur in either Australia or New Zealand. The record by H. C. Field in Ferns of New Zealand, pp. 145–147 cannot be accepted.

while the chloroplasts are confined to the peripheral cells. *Leptopteris hymenophylloides* with its flat leaf looks even more hygrophytic than *L. superba,* which has the segments of its ultimate pinnae incurved with the basal ones almost at a right angle to the rachis, giving the frond that appearance and feel to the touch which have earned the plant the name of "crape fern." But the former grows in much dryer forests than *L. superba* can tolerate, for this latter is altogether restricted to localities where the rainfall exceeds 150 cm. yearly, and where the air is always more or less saturated with moisture. Certainly the arrangement of the ultimate segments enables the frond for a time to hold more than its own weight of water, but the fineness and great number of these divisions lead to rapid drying. and the fronds of *L. hymenophylloides* remain if anything wet the longer of the two. Both

Fig. 1 Plant of *Todaea barbata,* 1.52 m. tall, growing in full sunshine near Mangonui, north of North Island of New Zealand. Photograph by L. Cockayne.

species form, at times, short trunks, those of *L. superba* being the larger, more or less conical in shape, and sometimes measuring 44 cm. in diameter at the base and 50 cm. in height. The colour of the fronds bears a relation to the intensity of the illumination, the leaves being blackish green in the most feeble light. So too does *Blechnum nigrum*, a fern of the moistest and darkest forest gullies, possess almost black fronds.[11]

The ferns noted up to the present have shown striking epharmony, but the examples next to be cited clearly show that misleading conclusions may be drawn from structure which apparently could possibly fit in with only one set of conditions.

Rangitoto Island, a volcanic cone rising out of the Hauraki Gulf at the entrance to Auckland Harbour, offers for plant colonization merely irregular blocks of lava, large and small. At the present time, although there are many bare patches, there is a surprising amount of vegetation, varying from isolated plants just gaining a footing to actual low forest which has formed a true soil. Leaving certain mosses and lichens out of consideration, the plants consist in large part of trees and shrubs which, if not xerophytes, have epharmonically assumed xerophytic adaptations. There are also certain herbs and ferns. Amongst the latter two filmy ferns grow right on the dry bare rock exposed to the full rays of the sun. These are *Hymenophyllum sanguinolentum* and *Trichomanes reniforme*, the former usually an epiphyte of forest or even open scrub, and so naturally attuned to a certain amount of drought, but the latter elsewhere to be found only in the wettest forests, where usually all is dripping with moisture. Its presence, but for the fact of this Rangitoto habitat, might well be taken as a certain sign of superabundant rainy days. It is true that *T. reniforme* is not confined to the bare lava alone. It grows also where there is a little soil on the rock, or rises out of a patch of liverworts. Or, it may be found at the base of clumps of *Astelia Cunninghamii* var. *Hookeriana* (Liliaceae), a xerophyte of the tussock form furnished with long, linear, rigid, coriaceous leaves, but this station

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[11] *Trichomanes elongatum*, which occupies the darkest and most hygrophytic station of all the New Zealand Hymenophyllaceae, has very dark-coloured fronds, which are frequently covered with many epiphytic mosses and liverworts.

is still xerophytic enough. Indeed there is no spot on the island where, but for its presence, one would dream that the plant could exist.

During dry weather both *Hymenophyllum sanguinolentum* and *Trichomanes reniforme* do protect themselves to some extent through curling their fronds or rolling them tightly, as the case may be. Moreover, *T. reniforme*, unlike most of the Hymenophyllaceae, has its fronds four cells in thickness As for the rock itself, it is extremely porous and must absorb a good deal of water during the frequent and heavy rains, so that the air surrounding such an apparently arid station may be much moister then might be expected. But taking all the above into consideration, it must be conceded, I think, that the fern is able to exist and to tolerate strong desiccation through what Shreve designates functional xerophily,[12] as in the case of various lichens, mosses and liverworts. Such a property in the case of *T. reniforme* can hardly be explained by any theory of evolution, but may rather be considered a specific character of its protoplasm, since, as aready explained, the species in question lives nowhere else except under intense hygrophytic conditions.

An interesting case of local discontinuous distribution is that of *Hymenophyllum Malingii*, a fern also otherwise noteworthy. This plant has narrow, more or less pendulous fronds 3 to 15 cm. long. They are opaque and reddish or silvery in colour through a dense covering of stellate hairs which quite hide the parenchyma. This latter does not form a flat leaf-surface, but, as Giesenhagen was the first to show,[13] consists of long cylindrical papillae which surround the pinnately branched leaf nerves. The spaces between these papillae are extremely narrow so that they form a richly developed capillary system which is shut off from the surrounding air by the covering of stellate hairs. Thus the outer surfaces of the chlorophyll-containing cells are in contact with water all the time, as much as those of a submerged water plant, unless during the very exceptional event of a protracted drought.

[12] Shreve, Forrest, Studies on Jamaican Hymenophyllaceae. Bot. Gaz., 51: p. 209, 1911.

[13] Giesenhagen, K., Die Hymenophyllaceen. Flora, 73, p. 449, 1890.

As for its distribution *Hymenophyllum Malingii* is altogether absent from the rain-forest in general. It is present only in those associations which contain as an important or dominant tree *Libocedrus Bidwillii* (Pinaceae) upon the trunks of which it grows, forming wide patches by means of its extremely slender branching rhizome. It appears to much prefer dead to living trees, but it is occasionally found on the latter, as also, I believe, upon living and dead *Podocarpus Hallii*.[14] The *Libocedrus* association occurs in both the North and South Islands. It is usually subalpine, but where it descends to a low altitude the fern is still always to be expected. The distribution of the association is widely discontinuous, as in the case of Banks Peninsula where *H. Malingii* in conjunction with *Libocedrus* at one time occurred while the nearest other example would be more than fifty miles away to the west. The species is also recorded from Tasmania, where it is stated by Rodway[15] to occur only on the trunks of *Arthrotaxis selaginoides*.

Gleichenia dicarpa is an extremely wide-spread fern in New Zealand growing fully exposed in the open and denoting wet, sour soil. The pinnae are plagiotropous in position, and frequently arranged in two or more tiers, one above the other. The ultimate segments of the pinnae are pouch-like beneath through the extreme recurving of the margin. This pouch-like form is virtually the sole specific character separating *G. dicarpa* R. Br.[16] from *G. circinata* Sw., the segments of which are flat. *Gleichenia dicarpa* var. *hecistophylla* (A. Cunn.) Hook. f. is the common heath or moor fern of Auckland. According to Cheeseman's specific description the "segments are strongly incurved beneath, sometimes as much as in the typical form, but variable in this respect." This character, however, I recently saw to be environmental

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[14] Also recorded by E. P. Turner on *Dacrydium intermedium* (Report on a botanical examination of the higher Waimarino District, p. 3, Wellington, 1910).

[15] Rodway, L., The Tasmanian flora, p. 290. Hobart, 1903. (Pinaceae.)

[16] According to the Index Filicum, pp. 321–322, *Gleichenia dicarpa* does not occur in New Zealand but *G. linearis* (Burm.) Clarke, while *G. hecistophylla* A. Cunn. = *G. alpina* R. Br. These conclusions I have no means of verifying as I write, and so am following Cheeseman's nomenclature (*op. cit.*, pp. 1117–1119), which does not affect at all the statement as to plasticity or the conclusion derived therefrom as to specific identity in two species held to be distinct.

merely, for in a number of individuals, which had leaves growing both in sun and shade, the sun leaves had strongly pouched segments, while those of the most intensely shaded leaves were quite flat, and various intermediate stages of "pouching" in harmony with the intensity of the illumination were present. In the case of *Gleichenia circinata* and *G. dicarpa*, unless there are other differences of specific value, the two "species" must be united, nor can either the form with flat segments or that with pouched be kept distinct, even as varieties.

Fig. 2 Upper part of frond of *Hymenophyllum Malingii*. Photograph by L. Cockayne.

A very similar case occurs amongst the spermophytes in *Olearia* *nummularifolia* Hook. f. and *O. cymbifolia* Hook. f. (Compositae). The inflorescence and florets are alike in both species, but the leaves are apparently most distinct, those of the former species being virtually flat, and those of the latter boat-shaped, through their strongly revolute margins. In free nature these distinctions hold and the two species may grow side by side in the same

Fig. 3 Colony of *Hymenophyllum Malingii*. Photograph by A. Hamilton.

subalpine scrub association. But cultivate *O. cymbifolia* in moist air and dim light or let it grow in the open in excessive shade, and the boat-shaped leaf is replaced by one that is flat. Here certainly there is greater stability of form than in the species of *Gleichenia* dealt with above, and the question arises as to what degree of constancy may be required in plants generally as a specific mark.

Up to the present we have dealt only with examples of natural distribution where the species have worked out their destinies without the disturbing influence of man, but in the case of the next fern to be spoken of, *Pteridium aquilinum* var. *esculentum*, its present distribution, even in recently colonized New Zealand, is certainly no measure of the part it played in the primeval vegetation.

The plant in question is confined to the Southern Hemisphere, and, though it may be considered a geographical species, the distinctions between it and the cosmopolitan *P. aquilina* are but slight. As to the abundance of the plant in virgin New Zealand, I am of opinion that, though it might be more or less common, it did not form that aggressive, almost pure, association which is the dominant feature of many parts of the region at the present time. No sooner is the forest destroyed in some localities, the heath burned or the moor drained ever so little than, as if by magic, the bracken fern gains possession of the ground. "Fern" to the settler is a specific term and in a land of ferns refers only to the bracken, which he knows to his cost is so difficult to eradicate. Where a bracken heath is well developed, it is a trial both to one's patience and muscles to force a path through the entangled mass of fronds, at times more than man-high.

The great spread of the plant is due to its rapid vegetative increase, its easy dissemination by spores, its capacity for reproduction after fire, and, not least, its rapid response to change in outer stimuli. Thus, according to reaction to wind, moisture, and light, it speedily varies from a strong xerophyte to almost a hygrophyte, so far as form and structure of leaf go. Less well known is the fact that it can become a scrambing and almost a twining liane. Mr. H. Carse and myself recently found a number of climbing fronds, some of which were more than 3 m. in length, growing in a low wood of *Leptospermum scoparium* on Reef Point, north-west Auckland. Pinnae were absent until the bright light was gained. The final portion of the rachis was green and succulent, and the distance between the pinnae in one example 46 cm. These latter were still coiled up and quite rudimentary, although the largest was 25 cm. long. In some examples the rachis was twisted and showed an evident tendency to twine. Such a case as the rapid spread of *Pteridium* under its new conditions in New Zealand, considered along with other examples of indigenous species becoming aggressive, should be of interest with regard to the origin of certain so-called primitive plant associations of Europe, for the new conditions are European rather than New Zealand. This is still more true with regard to the new flora and vegetation now in the making out of the firmly established host of introduced species, mostly European, and the much diminished aboriginals.

GUMMOSIS

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The phenomenon of gummosis has, perhaps, incited more investigation than any other plant pathological problem. This malady, evidenced by a gummous exudate from the fruit, twigs, larger branches, and trunk, has been observed wherever species of *Prunus* and *Citrus* are grown. In a recent memoir[1] the most exhaustive that has appeared in America, Butler has brought together the important facts in the observations of Trécul, Wiegand, Frank, Aderhold, Beijerinck and Rant, Mikosch, Ruhland and others who have investigated this disease. As a result of the work of these observers, it had been concluded that gummosis may be induced by any manner of traumatism which affects the cambial tissues. It may be brought about, on the one hand, by parasitic fungi among which are *Coryneum beijerincki* Oud., *Clasterosporium carpophilum* (Lév.) Aderh., *Sclerotinia fructigena* (Pers.) Schroet., *Cladosporium epiphyllum* (Pers.) Mart., *Valsa leucostoma* Pers., *Tubercularia vulgaris* Tode., *Botrytis cinerea* Pers., *Plowrightia morbosa* (Schw.) Sacc., and *Exoacus deformans* (Berk.) Fkl. Bacteria are also believed to be causal organisms. Again, any wound made by insect larvae, by freezing or burning, or by the use of chemicals or implements, may cause the disease in question. Butler's work, a confirmation in part of the views of earlier investigators, includes a distinct addition to our knowledge of the details of the earlier stages in gummosis. To the theoretical aspect of the problem he contributes hypotheses which diverge materially from those previously advanced regarding the nature of this malady. It is the present

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[1] Butler, O., A study on Gummosis of *Prunus* and *Citrus*, etc. Ann. Bot., 25: 107–153, pl. VII–X, 1910. Butler's memoir contains a bibliography of other authors referred to in this paper.

purpose to direct attention to certain questions raised in the mind of the writer during the reading of this memoir.

The salient features regarding the conditions which induce gummosis, as well as regarding the origin and composition of the gum, according to Butler's account, are as follows. It has been clearly shown that two conditions are essential to the development of gummosis. These two conditions are filled if, at once, the cambium is active and the tissues are in a high state of sapidity. Gummosis is due to the dissolution by hydrolysis of the walls of the embryonic wood. There occurs first a swelling, followed by a gelatinization of the primary membrane. Both membranes are rendered semi-fluid by a further absorption of water. The resulting solution collects between the contiguous cells and as a result they are detached from each other. The dissolution of the "third" lamella[2] proceeds centripetally. The gummy mass is therefore a mixture of the hydrolyzed cell-walls and the protoplasm of the disorganized cells.

Ruhland was of the opinion, from experimental evidence, that atmospheric oxygen, when it is permitted to penetrate to the young wood, acts upon the carbohydrate of the cell membrane and of the cell contents and oxidizes them into gum. Chemical analyses show, however, that these gums are hemi-cellulose derivatives and not oxidation products of carbohydrates. Sorauer was able to show that gummosis followed stimulation by an oxidizing agent. He believed, however, that this agent merely interfered with certain functions of the cell in such a way as to render active some zymogen already present in the cell. All the evidence points to the conclusion that while gummosis is in a certain sense autogenetic, yet it only results because of unusual stimuli. The relation between cause and effect in natural phenomena is often difficult to perceive or not easily explicable. For example the formation of zoospores in plants like *Ulothrix* and *Hydrodictyon* may be induced by weak solutions of sugar.

The Arabs have for a long time by empirical methods rendered dates non-astringent by treatment with the fumes of vinegar.

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[2] This terminology is unusual and the figures which accompany the paper do not indicate the corresponding structures.

Vinson[3] has shown that the same results may be obtained by numerous substances, and, moreover, has offered evidence that enzymotic activity is involved. Lloyd[4] has found that, whereas eight or more days' treatment with carbonic acid gas is usually required to render persimmons non-astringent, the same effect can be had in less than forty-eight hours when they are subjected to the same agent under increased pressure. In all of the examples cited, just as in the production of gummosis, the complete chain of events between cause and effect is not known. It does not then seem unreasonable to suppose that enzymotic activity leading to gummosis may be incited by any factor which would disturb the protoplasmic activity of the wood cells.

Beijerinck and Rant indeed hold that the formation of gum is in fact due to the presence of an enzyme, cytase, within the cambial cells. So long as these cells are alive it is unable to attack the cell-wall owing to the semi-permeability of the protoplasm with respect to the enzyme involved. Just as soon, however, as the embryonic wood cells become traumatic by the presence of fungi, bacteria, wounds, toxic substances, etc., the cytase escapes and attacks the walls of the surrounding cells. They offer as proof for the existence of cytase that the hyphae of *Coryneum beijerincki*, when present, are affected by gummous degeneration.

Butler, however, considers that gummous degeneration must be explained by some other hypothesis than the excretion of a cytolytic enzyme. Because of the vast accumulation of evidence of enzymotic activity in somewhat comparable cases in plants, it would seem that the burden of proof of the non-existence of enzymes should rest on him. He does not arrive at this conclusion as the result of micro-chemical tests for enzymes nor by attempts to isolate them, if one may judge by the evidence presented in his memoir. In fact no experimental evidence is presented in support of his view. He attempts to show that his observations cannot be made to harmonize with the assumption of the presence of

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[3] Vinson, A. E., The stimulation of premature ripening by chemical means. Jour. Am. Chem. Soc., 32: 208–212., 1910.

[4] Lloyd, F. E., Carbon dioxid at high pressures and the artificial ripening of persimmons. Science, N. S., 34:924–928, Dec., 1911.

enzymes. It is my purpose to consider further the several objections which he raises against the rôle of enzymotic activity in gummosis.

Gum pockets are fusiform in shape with the greater extension upwards from the initiatory center. Butler argues as follows. If gummosis is due to the action of a cytolytic enzyme diffusing outwardly from the moribund cells, it would seem that the disease should extend equally in all directions from it original center, analogous with the diffusion of solutes in a solvent. We should therefore expect a spherical gum pocket. In this, however, he overlooks the well known fact of the local action of enzymes in the cell. For example, enzymotic activity is concerned during the process of growth of fungi. At certain places, usually at or near the end of the hypha, the ferment causes a metamorphosis of the walls enabling the hypha to extend its length or originate a new branch. Fertilization in many fungi and algae is made possible only by the local dissolution of the contiguous walls of the antheridium and oogonium through the action of a solvent. The escape of the zoosphores in forms like *Saprolegnia* and *Achlya* is effected (either apically or laterally[5]) by the gelatinization of the apex of the sporangium. The penetration of many parasitic fungi is dependent upon the local excretion of an enzyme. Elfving's[6] observations on the pollen of grasses point to the secretion of cytase at the tip of the pollen tube enabling it to penetrate the tissues of the style. Since protoplasm is not a homogeneous colloid, as evidenced by such structures as plastids, chromosomes, sap vacuoles, etc., we must expect localization of function.

But even if we assume the equal diffusion of the solvent, the affected area would not necessarily be spherical, since autolysis may overtake cells seriatim in one direction and not in another. Lloyd[7] has observed a condition which illustrates the point in question. He finds that in the fruit of the Japanese persimmon, aside from the tannin-idioblast in the mesocarp, the cells of the

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[5] Coker, W. C., Another new achlya. Bot. Gaz., 50: 381–382, 1910.

[6] *Vide* Green, Reynolds, Fermentation, p. 98.

[7] Lloyd, F. E. The behavior of tannin in persimmons, with some notes on ripening. PLANT WORLD, 14: 1–14, 1911.

mesocarp and endocarp, are apparently alike. During ripening, however, the cells of the endocarp do not become mushy or to any marked degree deliquescent, while as a result of pectin digestion the walls of the mesocarp become quite watery. The fact that gum pockets are asymmetrical can not be considered as proof either for or against the presence of cytase.

The unilateral excretion of cytase in the production of gummosis does not appear to present insurmountable difficulties, inexplicable by cytolytic activity nor is such a phenomenon at all in opposition to other known cases. A most remarkable case of unilateral diffusion and digestion by an enzyme occurs in *Coprinus atramentarius.*[8] Not only do the basidia undergo autodigestion from below upwards on each gill, but each cystidium disappears a few minutes before the basidia in its neighborhood come to be involved within the upwardly progressing zone of spore discharge.

A further argument advanced by Butler against the hypothesis of enzymotic hydrolysis is called forth because of the manner in which he finds the cell-wall to be attacked. He reasons that the enzyme "would have to attain the power of action only after having diffused out into the secondary and primary lamellae, thus only being able to attack the third membrane, which it permeates, after having hydrolyzed the former and that in a centripetal manner. Such a mode of action would be indeed peculiar." If the cell-wall, including the primary membrane, were homogeneous in its chemical composition and only one enzyme were operating, his position would be tenable. We know, however, that the wall is not homogeneous and that two or more enzymes are necessary to its digestion. It has long been known that there is a difference of composition of the middle lamella and the secondary membrane. Payen[9] pointed out that the middle lamella is composed, entirely or nearly so, of calcic pectate, which opinion has been confirmed by Mangin.[9] Pectase, which acts upon this substance, if secreted by the protoplast might per-

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[8] Buller, A. H. R., The function and fate of the Cystidia of *Coprinus atramentarius.* Ann. Bot., 24: 613–629, pl. 50–51, 1910.

[9] *Vide* Green, Reynolds, Fermentation, p. 279.

meate the secondary and tertiary membranes without attacking them. No better proof of the specific action of enzymes can be advanced than that given by Jones[10] in his work with soft-rot organisms. An interesting comparison is afforded us by *Protomyces macrosporus*[11] in which the middle layer of the wall is gelatinized and the endosporium remains intact to become the wall of the extruded sporangium.

Attention may also be called to the observation that cells under certain conditions, which were observed to be floating free in the gum, vanished upon the addition of water, while under other conditions free cells no longer vanished upon the addition of water. How this proves that protoplasm plays no rôle in gummosis and that the cell wall is *ab initio* the seat of the malady is not clear. If we assume that the walls of the cells affected by gummosis have been rendered almost soluble by enzymotic activity, and there has been established an osmotic equilibrium between the colloids within the cells and the gum mass without, contact with water might easily cause the cells to imbibe enough to suddenly burst them and rather quickly complete the hydrolization of the cell-wall. This condition seems to be analogous to the phenomena which are exhibited by tannin masses taken from softened persimmons.[12] Such tannin masses, when the semi-fluid substance of the disintegrated cell-walls is diluted or replaced by water, will quickly absorb enough of it to cause the cells to burst.

In studying the cells which did not vanish, Butler finds that by staining with Böhmer's haematoxylin, the gum is stained and the protoplasm is not affected, but by staining with aniline blue 2V. the protoplasm is colored and the gum is not affected. By this differential means he could determine exactly when he was dealing with gum and when with protoplasm and arrives at the conclusion that "the cell contents are free from gum and take no part

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[10] Jones, L. R., Pectinase, the cytolytic enzyme produced by *Baccillus carotovorus* and certain other soft rot organisms. N. Y. (Geneva) Agr. Expt. Sta., Technical Bull., 11: 291–368, 1909.

[11] *Vide* DeBary A., Comparative morphology and biology of the fungi, mycetozoa and bacteria, p. 171.

[12] Lloyd, F. E., The tannin-colloid complexes in the fruit of the persimmon, *Diospyros*. Biochemical Bulletin, 1: 7–41, pl. 1–3, 1911.

in its formation from the initial stages of gummosis until they finally vanish upon the gelatinization of the tertiary membrane." The fact that he finds no gum in the protoplast cannot be taken to prove that the protoplast takes no part in gum formation. All that such a micro-chemical test proves is that there is no gum within the protoplast. This is not at all surprising and is exactly in accordance with the conclusions of other investigators of the secretory products of plants. Tschirch[13] states that the presence of resins is not the direct result of protoplasmic activity but of enzymotic activity within the wall itself.

In conclusion, therefore, there appears to be no reason, in the evidence submitted, for disbelieving the rôle of enzymes. Until the immediate cause of gummosis is demonstrated to the exclusion of enzymotic activity, it remains more reasonable to adhere to a view which, at any rate, has the support of a large body of collateral evidence to substantiate it.

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[13] Tschirch, A., Die Chemie und Biologie der pflanzlichen Sekrete. Leipzig, 1908.

BOOKS AND CURRENT LITERATURE

Applied Biology.—It is the good fortune of the authors of this book[1] to have produced a text that, in larger measure than any other text yet published, meets the requirements of a high school course in biology. In the first place the title is not a misnomer. It is a book on biology, and not two books in one binding, one on botany and the other on zoölogy. It is also, in a broad and scholarly way, "applied." The author recognizes that there are applications of fundamental importance in other than the commercial sense, and which have reference "to human life in its combined intellectual, aesthetic, economic, and hygienic outlook." The entire book is, in effect, a protest against the unfortunate present day tendency to commercialise the high school course of study, and especially the science portion of it.

In Part I (pp. 1–144) the pupil is introduced to the Principles of Biology; in Part II (pp. 145–298) he studies illustrations of these principles as embodied in types of plants; in Part III (pp. 299–454), as embodied in types of animals; and in Part IV (pp. 455–573) as applied to human structure and life. It is of interest to note how a different order of topics is handled with equal pedagogical advantage in Parts II and III, the study of plants proceeding down the scale from higher to lower; that of animals, up the scale from lower to higher. The Gordian knot of the best order of topics has been cut,—the only way Gordian knots are ever successfully gotten rid of: it ought now to be recognized as non-existant for every one. Doubtless the author would be among the first to assert that his treatment might have been reversed with entire success, going from the structurally complex to the structurally simple with animals, and *vice versa* with plants.

No doubt the above encomiums will have more force if attention is called to a few unpraised points, ferreted out of the mass of good with some difficulty. On pages 6 and 7, element, molecule, and atom are used, but so far as the reviewer can find, nowhere in the book defined.

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[1] Bigelow, Maurice A. and Anna N., Applied Biology: An Elementary Textbook and Laboratory Guide. Pp. xi+583, figs. 166. New York, The Macmillan Company, 1911 ($1.40).

On pages 55 and 67 the teaching is that breathing and respiration are synonymous, that plants "breathe," and that the taking in of oxygen and giving out of carbon dioxide together constitute respiration. Doubtless there is plenty of weighty precedent for this view, but it is very unfortunate nevertheless, and ought no longer to be perpetuated. Our understanding of metabolic processes has now reached a stage when we recognize respiration as, in essence, a cell-process in both plants and animals, accompanied (usually but not always) by the exchange of gases just referred to. It is this exchange of gases to which, in animals, the term breathing should be restricted; in plants, and in some animals, *e.g.*, the earthworm, it is not breathing, but simply the physical process of diffusion. The reviewer is firmly of the opinion that this terminology is not only more nearly adequate to our present state of knowledge of these processes, but is pedagogically desirable as conducing to clearer thinking.

Greater uniformity is desirable in presenting the concept "cell." On pages 69, 70 and 71, the cell is presented as a cavity "containing living matter," while on pages 41 and 79, it is described as "composed of cell-substance." The two conflicting views occur together on pages 69 and 71. Also on page 71 it is stated that the slippery-elm bark owes its peculiar property to the cambium between the bark and wood, instead of to the mucilage of the inner bark.

From paragraph 77 (p. 80) the pupil will probably get the idea that dorsal and upper, ventral and lower are synonymous. This is especially misleading with reference to plants; the normally lower surface of the expanded foliage leaf, for example, is the morphologically dorsal surface. The flounder is an easy animal exception for a botanist to think of. On page 90 it is stated that the osmoscope experiment demonstrates that the molasses employed "attracts" the water, and again on page 92, the attraction hypothesis of osmosis is the only one referred to. The assertion at the top of page 101, that "most plants without chlorophyll are saprophytes," is doubtless open to question, if not certainly incorrect; while a few lines below (¶99) parasitism is overlooked in the statement that non-chlorophyll bearing plants must absorb their carbohydrate food from the "decaying" bodies of other plants or animals.

We read on page 109 that "no one has yet found any other substance except starch with which iodine solution gives this peculiar blue color seen in starch." As plant physiologists well know, not only are there other substances besides starch that will give the blue reaction with iodine but some starches will not give it.

In the last paragraph on page 102 the teacher is directed, for a demonstration, to place plants in darkness for *one* day in order to empty the leaves of starch. One of the plants suggested is the nasturtium (*Tropaeolum*). Miss Eckerson showed in 1899 that it requires two nights and one day, or about 48 hours, for nasturtium leaves to become emptied of starch. See also paragraph 101 on page 104. On page 103 is the statement that "Starch formation is most rapid in direct sunlight," whereas, as Blackman showed in 1905, the optimum of light varies with the percentage of CO_2 available, and for the percentage of CO_2 normally present in the atmosphere, leaves, especially in summer, cannot use all the light of direct sunlight for photosynthesis.

It seems unfortunate to have repeated again, especially in a first-course text, the erroneous notion that plant and animal metabolism are, in any fundamental way, unlike, and especially that photosynthesis and the synthesis of fats and proteins constitute the constructive metabolism (anabolism) of plants. It only obscures the essential identity of metabolism (*i.e.*, the construction and continuous destruction of *living substance*, not of carbohydrates, etc.) to class the synthesis of foods as a part of plant metabolism. Photosynthesis is no more a part of plant metabolism than is the ascent of sap, though both processes involve, and are accompanied by metabolic change. The authors' paragraph at the top of page 126 really implies that animals have no constructive metabolism.

No biological error is dying harder than the idea that Linnaeus introduced the method of binomial nomenclature (p. 133). A more excusable perpetuation of a misconception of minor importance is the classification (p. 194) of the clover leaf as palmately compound.

From the first full paragraph on page 143, stating that scientific names are in reality not difficult and that there are many advantages in their use, we are led to expect them later on, but for 154 pages dealing with plants (pp. 143–297) we find hardly one scientific (Latin) name of the plants referred to except in the legends of the illustrations. Not even is the now rather common *Agaricus*, or agaric, used for the "meadow mushroom," nor *Amanita* for the deadly "toadstool." "*Sphagnum*" and "*Polytrichum*," however, come as a surprise on page 242. The reviewer believes that pupils are easily repelled or "scared out" by Latin binomials, and that they should be avoided, but there is also much truth in the author's statement on page 143, and it seems as though it would have been a distinct advantage to have given the binomials, at least in parentheses. However, the authors have taken the safe course

The illustrations are noticeably few in number, but those used really illustrate. The treatment of human physiology and hygiene seems specially weak on the experimental side, where there are so many valuable observations and experiments, many of which may be made at home. This, of course, brings up the whole question of the advisability of sandwiching in laboratory directions and text for reading. Such is the authors' plan, and the reviewer is sorry he cannot pronounce it good. Many others can and do, however.

To state the points that the reviewer (and, he believes many others with him) would designate as giving a peculiar and almost unique value to this text would occupy much more space than has already been consumed. But these points the authors will not want to change in their second and subsequent editions. The other points we hope they will wish to change. In their treatment of spontaneous generation (*e.g.*, p. 347), of the physiological effects of alcohol, of mammalian reproduction, and of the present status of knowledge,—that is, that there is yet much to be found out (*e.g.*, p. 94),—the authors are specially sane and sound. The experiments with yeast (pp. 268, *et seq.*) are most admirable. Since the authors' chief interest is zoölogy, we have no doubt but that their treatment of Parts III and IV, only incidentally referred to in this review, will be considered even more successful than that of Parts I and II.

The book is remarkably free from typographical errors, the style is clear and attractive, and, *although there is not any such word* (in this sense) we may quote from a host of publishers' advertisements and say that this book is unusually "teachable."—C. S. G.

NOTES AND COMMENT

The latest issue of the Transactions of the San Diego Society of Natural History (vol. 1, no. 3) contains a remarkable direct reproduction of an original photograph of red snow, made in the natural colors by the Lumière process. It is the work of Mr. F. A. Carpenter, who took the autochrome in July last on Lambert Dome, at an altitude of 10,000 feet, in the high mountains above the Yosemite Valley. It is of interest not only as an example of the recent art of direct color photographing, but also as the first representation of snow-fields stained with *Sphaerella nivalis.* Sky and clouds, the rocks and pines in the foreground, and the patches of red snow on the flanks of the mountains are all reproduced faithfully in their natural colors. Red snow was abundant during the last summer at the high Sierran altitudes about the Yosemite, and fortunately there was a goodly number of botanists on their vacation outings who had an opportunity of observing it. It is believed that this is the most southern station on the Pacific coast of North America at which this alga has been observed. A plant of such wide distribution may, however, well be expected on Mount Whitney, where there are fields of perpetual snow. Mr. Carpenter contributes an interesting account of his observations of the red snow, and of the processes by which color photographs are made and reproduced. The San Diego Society are to be congratulated on the value of the papers in this number of its Transactions, and on its typographical excellence. —S. B. Parish.

Dr. Isaiah Bowman, Assistant Professor of Geography in Yale University, has written a text entitled Forest Physiography (John Wiley and Sons, 1911), which cannot fail to interest a much wider audience than the students of forestry, to whom it is primarily addressed. The opening chapters give a brief treatment of the soil from the standpoints of the geologist, the soil physicist or chemist, and the plant physiologist. The influence of physiographic and climatic conditions in determining the forest regions of the United States is outlined. The greater part of the book is given to a description of the physiographic features of some twenty subdivisions of the country. The geological structure is given only the attention that is necessary to an understanding of the surface forms, while the climatic conditions of each province are kept in constant view and frequent allusions are made to the principal features of the vegetation.

We have received from The American Book Company a new elementary text, A Practical Course in Botany, by E. F. Andrews. The author has aimed to make the high school course in botany more palatable by emphasising the bearings of the subject on agriculture, economics and sanitation. The book is not so much an *omnium gatherum* from all departments of botany as some of the recent texts have been, but is rather a sound frame-work of morphology with constant allusion to the functions of plant organs. The Practical Questions at the close of each chapter are very well designed to connect the random observations of students with the orderly facts of the text, and go to prove that it is very easy to make an elementary course in botany interesting, whatever other characteristics it may happen to have.

THE CHOOSING OF A PROBLEM FOR RESEARCH IN PLANT PHYSIOLOGY

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The increasing number of botanical students who are inclined toward the physiological aspects of the subject, and the clearness with which present conditions seem to indicate the possibility of many sided success for such students, have impressed upon the writer the idea that plant physiology is at the present time in a stage of its development which is perhaps more critical than any through which the science has passed. That the immediate future will show a great increase in the number of men whose main line of activity lies in the field of plant dynamics is clearly augured by the present status of this line of study. The advance of a science is always closely linked with its application in the arts, and the awakening of many minds to the fundamental importance of the content of plant physiology in agriculture and forestry is rapidly taking, or has already taken place. This may explain the increased demand for physiologically trained men, a demand which, during the past few years has quickly and almost suddenly outstripped the supply. At any rate, the increased demand is a fact, and a correspondingly increased supply is practically assured. But it takes many years to make a competent physiologist, even in a restricted field of this broad subject, and competition for the most desirable positions in American institutions seems not likely soon to become very keen. Under these conditions many of the younger students of plants, and apparently also a goodly number who have made their start in chemistry, are turning their attention to plant physiology as a promising field for a life-work.

After the first draft of these notes had been written, it was well said in these pages,[1] that "the entrance of any person into science in a serious manner is usually connected with the work carried out during his candidacy for the doctor's degree." It is this consideration together with that stated at the end of the last paragraph, which makes the present seem to be such a critical time in the development of physiological science with reference to plants. For, as the note just cited points out, the facilities for guidance into the realm of this subject are none too good in the majority of American universities. If the university student has made up his mind that the physics and chemistry of plant processes is his chosen field, he is perhaps not apt to be discouraged by instructors whose bent of mind makes the statics and the past history of plant forms most interesting to them, but it is obvious that he will not be especially aided, and, with the best of intentions on the part of his leaders, he is apt to be obliged to seek his experience by "hook and crook," without any very clear outlook into the possibilities of the future.

Conversation and correspondence with a considerable number of beginners who belong to the class here considered, convince the writer that such persons are frequently at a loss as to how they should try to make their entrance into physiological work, as to what sort of a problem they should attempt, and as to where they should attempt it. In such cases it becomes apparent that indecision here, as always, arises from a lack of serviceable criteria by which to compare and judge. Without some sort of criteria the beginner is too often constrained to flounder rather than swim. Furthermore, a perusal of current publications in plant physiology pointedly suggests that one of the most imminent perils of the beginner in this sort of scientific research lies in the relative ease with which he may unconsciously enter a *cul de sac*, thus perhaps becoming, with his later development, a true expert in some field where relatively few connections with other lines of human activity render the most painstaking observations and the deepest ponderings of comparatively little immediate importance.

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[1] D. T. M., Plant World, **14**: 252. 1911.

There are still those who maintain that any piece of scientific investigation carefully done and published must of necessity bear great fruit in future years, but such views are usually met with in those who do not seriously attempt to keep up with the progress of the current literature of their science; to him who makes this now practically hopeless attempt it becomes apparent that science advances almost entirely along those lines where interest to a large number is maintained, for we think about and work with what we read, and we are perforce compelled to read only what interests us most in the present voluminous mass of scientific writings. From the practical side, at any rate—and this side usually looms large in one way or another on the horizon of the beginning scientist—it is desirable for both worker and science that a general interest be commanded, as far as possible, by the line of work which the beginner chooses to undertake.

The suggestions to be embodied in the sequel have come to the writer from time to time during the past decade. They are here brought together in an attempted logical arrangement, partly from a desire to aid beginners in choosing the line of work with which they hope to make their debut as investigators, partly to clarify the writer's own views on the subject (with the hope that he who reads and disagrees may not do so in silence).

With the consciousness of the overwhelming inadequacy of any presentation such as this, there is a human satisfaction in pointing out that the following paragraphs involve almost nothing that is original, excepting the mode of statement. Doubtless every idea brought out below has been long held by others. It is also almost certain that every point here made is incorrect or inadequate to some degree: if the stating of these ideas may distract attention, for a few moments, from the concrete questions of the laboratory and field, and may arouse a train of thought by which it may be sought out wherein these points are wrong and why they are so, then the future of our knowledge of plant dynamics should surely be the gainer by as much as is lost to the immediate present through such distraction.

The choice with which we have to deal appears to depend, in general, upon three conditions: The view-points of the older men with whom the supposed student comes mostly in contact, his own previous training and present ability and interest, and the future possibilities which he sees in the line of work to be chosen. We do not need to consider here the various view-points held by the present leaders in the science, nor do we need to dwell upon the various sorts of personal interest and scientific and other training with which it is now possible for a student to present himself at the door of a research laboratory. It will rather be the aim of these paragraphs to attempt a tentative discussion of the innate possibilities which characterize the main groups of problems, from the array of which choice for a first research is likely to be made.

LINES OF PHYSIOLOGICAL ACTIVITY

1. The simplest form of plant physiological study, as of other scientific investigation, appears to be the qualitative description of occurrences in nature. As examples of this kind of inquiry may be mentioned such discoveries as the exhibiting by the majority of higher plants of responses to light direction and to the force of gravitation, to water supply and to water loss, and to the presence or absence of certain chemicals in the surroundings. Before the theories of organic evolution became the center of inertia about which the main mass of biological inquiry revolved these qualitative observations made up a large part of the science; thus a taxonomy without its basis in phylogeny consisted in such facts as this, that under the natural conditions certain plants develop a burning juice and cruciform flowers, while others as persistently produce bilabiate flowers and an aromatic, volatile oil. Fortunately, so much of this foundation in natural fact has already been accomplished by the great botanical pioneers, that it is now unnecessary for anyone to set out primarily upon this line of categorical description. New and "interesting" qualitative facts about plant phenomena are no longer apt, *per se*, to attract much attention among physiologists. Nevertheless, no science can advance without continued activity in descriptive lines, and this sort of study makes up a less interesting portion of all contributions to physiological science today, the interest

therein lying not in the phenomena themselves but in their relation to other phenomena. While descriptive botany, in all its phases, is and must ever remain the introductory chapter through which the beginner best enters the subject,—just as one enters the field of a great literature by learning mere facts of the meanings of letters and word-signs—yet this is assuredly not now to be considered as an eminently promising line for a productive life-work.

2. The next step after qualitative description is the *relating* of the discovered phenomena to one another and to phenomena without the plant. This activity leads at once to the formulating of hypotheses and the institution of experimentation, upon which true physiology now depends for its basis of separate facts. But facts may be related in many ways. If we relate plant happenings with reference to time, our activities will be classed as phylogeny and ontogeny. If we relate them with reference to space, we work in anatomy and that part of ecology which deals with geographical distribution. If we relate them to their effects, to the results which they bring about, our work is teleology. Finally, if we relate them to their physical causes, we are studying plant physics and plant chemistry.

Only the last of the above methods of relating phenomena comes properly within the realm of physiology. Nevertheless, the fundamental concepts of cause and effect early became in some way confused in the minds of biological students, and the physiological literature abounds in teleological considerations. Thus, as an obvious example, one may read that horizontally placed stems bend towards the source of one-sided illumination in order to bring the leaves into the usual light relation, a quite teleological statement. Its etiological counterpart might be, that this bending takes place *because* of unequal lengthening of tissues upon the shaded and lighted sides of the stem, and *results* in bringing the leaves into their usual position with reference to light. Failure sharply to distinguish between proximal cause and effect has greatly retarded the advance of our knowledge of plant processes, so much so that the future science of physiology promises to be rather thoroughly reformed; its renascence is already making rapid strides. This consideration cannot be too strongly impressed upon the mind of the beginner who hopes to devote his energies mainly to the study of the existing relations between phenomena within and without the plant.

3. No very great progress toward a knowledge of causality can be made by the study of qualitative relations; quantitative descriptions of the phenomena involved and of their concomitant relations must soon become requisite as advance is made. It thus comes about that the main body of the activities of present-day physiology has to deal with measurement. Furthermore, quantitative description now frequently serves as an end in itself, just as qualitative description once did; biometrics and floristics are preëminently quantitative sciences, but they do not necessarily imply any direct seeking of fundamental physical causes, and phylogeny is rapidly becoming quantitative through the new science of experimental evolution. Since *heredity*, with the constancy and inconstancy of which qualitative evolution dealt, was but a name for an exceedingly complex series of physiological processes, it is not surprising that the new science of experimental evolution or of inheritance should be rapidly becoming physiological in its methods. Upon the latter is being rapidly built up the art of plant breeding, in which many of the findings of the science immediately find application.

This is the latest development of physiological study, to measure and relate the untold conditions which are causally connected with the numerous plant processes. That the future of this development will furnish wonderful advances is assured. It is mainly in this field that the demand for well-trained physiologists has so strongly developed recently, and it is with quantitative problems in physiology that our beginners in physiology should have to concern themselves.

SUGGESTED CRITERIA FOR THE JUDGING OF A PROPOSED PROBLEM

1. From the above considerations we are forced to place at the head of our list of requisites for a beginner's problem in research, that it should be of a quantitatively etiological nature, it should deal in a quantitative way with the causal conditions

which control some phase of organic activity. Whether the controlling factors dealt with are immediately effective or far removed from the controlled processes will naturally depend upon the progress which has previously been made in the physical analysis of the phenomena involved. It is with the less thoroughly analyzed phenomena of living beings that experimental science grades imperceptibly into observational. But, even where conditions cannot be artificially controlled, as in the modern experimental study of organic evolution, the conditions furnished by nature, both within and without the organism, may be measured and compared as great complexes. Thus quantitative studies of causality may be carried out without experiments, though not without physical measurements. Here, however, we pass out of the science of physiology as usually defined.

2. The problem chosen should be circumscribed, definite and specific. At the same time, it must be appreciated how this particular problem is related to other similar specific questions, the whole series covering some broad and general field. It frequently happens that a problem which attracts and fascinates a graduate student is far too broad to be rationally attacked, sometimes the mere breadth constitutes an attractive feature and throws a false glamor over the entire proposition. Such a question should be separated into partial questions and these attacked singly. The attempting of too broad, and hence, too indefinite a problem in his earlier years of research has worked lasting injury upon many a man of science.

The ideal problem for a beginner should be capable of statement, on *a priori* grounds, in the form of several alternatives; all the logically possible answers to the questions may be advantageously erected into hypotheses, and these may be tested in order. This sort of a problem conduces to logical thinking and must leave its sterling mark upon the mind in later years. Furthermore, it is economical of energy and time, and the end of the chosen piece of work is more or less clearly in view at the beginning. To bring a problem into this condition requires, of course, a large amount of thought at the outset; this might well tend to retard the progress of the generally prevalent idea among university students, that ability to carry out scientific research depends largely upon a knowledge of the experimental methods which have already been used.

3. The satisfactory problem must, of course, be capable of experimental treatment with the knowledge and facilities which are available. The beginner should not be called upon to devote too much time and energy to the devising of methods and the obtaining of apparatus. If he be misled in this he almost surely becomes more interested in the methods than in the results obtained by their employment. This does not imply that the methods to be used should all be familiar to the worker at the start, only that they should be accessible in the literature, so that he need not actually devise them. The tendency of the circumscribed problem toward narrow training is best combatted by having the problem, narrow though it be, of such nature that it leads far into the literature of chemistry, physics and animal physiology.

4. Apparent importance to the science as a whole is a very important criterion in our series. For the best results in all ways, the selected question should be one that interests both the theoretical and the practical worker. The old proverb, *mens sana in corpore sano*, may be applied, with little alteration, to a science as well as to a man; that science is the most successful in purely theoretical lines which does not hold itself aloof from those practical questions of ordinary life which it alone is capable of answering. As the practical applications of chemistry and physics have aided greatly in their development, so the application of plant physiology to the problems of agriculture *et cetera* should greatly accelerate the development of the theoretical aspects of the subject. Furthermore, as has been pointed out, it is probably in the practical application of physiology that many of the most desirable opportunities are apt to occur, and herein lies the greatest hope for the rapid development of the science in general.

The question of the theoretical importance of a given problem is not so easily settled as is that of its practical weight: it requires something of a prophet to judge rightly in this regard. A good way to attack this question is to ask, will any chapter of the science (as it stands at present) be fundamentally altered by the proposed study? It is too much to demand that the beginner should appreciate even a majority of the various ways in which a proposed research may bear upon the general science, but he will surely be able to discern some such important bearings. Usually his aim will be to test some proposition that is regarded as settled, but upon logically insufficient grounds, or to investigate some causal relation upon which there is a difference of opinion; without some such aim his interest is not apt to be aroused. The worker should see clearly *some* general and fundamental importance in his work, the more the better, we should think.

It is perhaps not out of place here to call attention to the fact that a superficial study of a little known relation is often as important in the development of a science as is a research upon the details of some better-known and already more thoroughly analyzed phase. The word superficial is not here used in any derogatory sense; it is intended to denote literally the study of the *outside* of the problem, where the inside is not yet approachable. Such superficial studies are the work of pioneers, they are adapted only to the exceptional beginner in research.

5. It is advantageous to the general and symmetrical development of a science, and especially desirable in plant physiology at present, that beginners be led as often as possible to take up questions which seem momentarily to be suffering relative neglect. While this turning out from the beaten path may often seem temporarily to injure the prospects of the beginner for a satisfactory career, yet if the problem selected fulfills the conditions of the criteria already suggested, this drawback is only of a temporary nature. A good piece of work in a relatively new field often attracts more attention finally than a better one in a well-worked portion of the science.

6. Since all physiological problems involve the use of some organism or organisms, the choice of these comprises a part of the choice of a problem. Primarily, such forms should be subjects of the experiments as are best adapted to the methods involved. Secondarily, of two plant forms equally suitable for the work in hand, that one should be chosen which is most widely known,

which, in and for itself, interests the greatest number of people. Ground for this statement lies partly in this very interest, and partly in the greater possibility that certain by-products of the proposed research may give rise to practical application in agriculture, horticulture, forestry *et cetera*. If *purely* practical aims are to be decried in a scientist (and, as such, they are surely incompatible with science), the active avoidance of any studies which might be applied is as egregious an error in the opposite direction. Had more doctors' theses in the past been based upon work with ordinary cultivated plants there might now be more sympathy manifested between pure scientists and students of agricultural operations. The science of plant physiology is now greatly in need of the general interest and facilities for work which come to a science through its practical application, and the art of plant-production needs the pure science to as high a degree.

NOTES ON THE ECOLOGY AND ECONOMIC IMPORTANCE OF *NEREOCYSTIS LUETKEANA*

A CONTRIBUTION FROM THE PUGET SOUND MARINE STATION

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Nereocystis luetkeana is the most abundant kelp of the Puget Sound region. The huge size of the individual plants, the fact that its bladder-like float is always at the surface of the water where it can be seen, and the fact that it forms dense beds covering such large areas bring it to the attention of every observer who crosses the waters of Puget Sound. Attaching itself to rocks by means of its powerful much-branched holdfast, it thrives in strong tideways. The slender rope-like stipe is strong and flexible. It enlarges upward into a hollow pneumatocyst which gradually increases in size until it terminates in a hollow bulb at the top. The pneumatocyst of a mature specimen is commonly constricted slightly just below the bulb, upon which are borne numerous slender ribbon-like laminae. These, as MacMillan[1] has observed, appear on hasty examination to be two groups of fronds, but on more careful examination it is seen that there are really only two fronds and that these are divided so nearly to the base as to give the appearance of numerous ones. *Nereocystis luetkeana* is known as the "bladder kelp." In the Puget Sound region the fishermen and navigators more commonly speak of it simply as "kelp." It is abundant from the Shumagin Islands in Alaska to Santa Barbara channel on the coast of California.[2]

The work on which this article is based was done at the Puget Sound Marine Station during the summers of 1908, 1910 and 1911.

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[1] MacMillan, C. Observations on *Nereocystis,* Bull. Torr. Bot. Club, 26: 273. 1899.

[2] Setchell, W. A. and Gardner, N. L. The algae of northwest America. Univ. Cal. Pub. Botany, vol. 1. 1903.

In the spring of 1911 Dr. Frank K. Cameron in charge of the fertilizer investigation in the Unites Stated Bureau of Soils wrote to Director Kincaid requesting the coöperation of the station in procuring the facts about the ecology and distribution of the kelps of the Puget Sound region. The writer undertook the work and spent a large part of the summer in making observations on the kelp beds and preparing dried material to be forwarded to the Bureau of Soils for analysis. He was assisted in this work by S. M. Zeller a graduate student at the station.

Fig. 1 Bed of bladder kelp at low tide at Kanaka Bay, San Juan Island, Washington. Photograph by S. M. Zeller.

The anatomy and development of this species have been discussed by MacMillan,[3] and the literature of the subject fully cited. He calls attention to the presence of sieve tubes, mucilage canals, secretion cells, cortex, central cylinder, a cambial zone, and tegumentary and photosynthetic tissue, and concludes that the degree of differentiation is physiologically equivalent to that in higher plants. During the summer of 1911, Zeller removed the fronds from several *Nereocystis* plants growing near the laboratory of the Puget Sound Marine Station and in every case the plant

[3] *Loc. cit.*

soon died. He also observed that the soral patches in which the spores are produced disappear from the frond with the maturing of the spores in them. This gives a very ragged appearance to the older fertile fronds. Frequently young soral patches may be found near the base of a frond, and mature ones in the middle portion while large open spaces nearer the tip mark the places where the older ones have disappeared.

Fig. 2 Portion of two laminae of bladder kelp showing part of a soral patch in each at the left, and two openings where the tissue has disappeared from the upper one when the spores were mature. Photograph by S. M. Zeller.

The duration of this plant has been discussed by Frye[4] and Setchell.[5] The writer of this paper has frequently collected specimens not exceeding 4 cm. in length during June, July and August. Whether these were produced from spores of the same season or from spores resting from the previous season he has no means of knowing. Frye has found young plants up to 2.5 m. long in March and up to 6 m. long in May, but evidence as to just

[4] Frye, T. C. *Nereocystis luetkeana*, Bot. Gaz., 42: 143. 1906.

[5] Setchell, W. A. *Nereocystis* and *Pelagophycus*. Bot. Gaz., 45: 125. 1908.

when germination took place in these cases is lacking. It scarcely seems probable to the writer that the spores of this plant would rest from midsummer until the following spring. Setchell, however, has actually followed "the same group of individuals through their life history and the result shows that the period of active existence is about nine or ten months and within the period of one year." He finds that they appear in February and March and disappear in December or January. In the Puget Sound region the plants reach the surface of the water in early summer and disappear by drifting loose, in late fall and early winter. This certainly suggests an annual plant and in reporting on this species with reference to its probable economic importance the writer has regarded it as an annual, although he has himself seen no evidence as to whether the spores germinate in mid-summer as soon as they are discharged or whether they rest until the following spring and then germinate.

The authors cited above (*l.c.*) have discussed the length of this plant and have fully cited the literature of the subject. The writer of this paper has never known of a specimen of the plant exceeding 24 m. in length. A plant of that length was measured by Zeller at the Puget Sound Marine Station in July, 1911. Frye reports individuals 21 m. in length. The writer estimated the length of many specimens in the vicinity of Friday Harbor, Washington, during the summers of 1908, 1910 and 1911 and in various parts of the Puget Sound region during 1911, by pacing them and has never found one exceeding 23 m.

There are evidently three principal factors that determine the habitat of the giant kelps, the depth of the water, the movements of the water, and the character of the bottom. The writer has frequently determined roughly the depth of the water in which the large kelp beds are found in the Puget Sound waters and along the American shore of the strait of Juan de Fuca by pulling up the kelp including the holdfast and measuring the stipe and pneumatocyst. By this method the maximum depth of water found in any of the kelp beds was 8 fathoms at high tide. Vigorous plants forming dense beds are frequently found in not more than 5 fathoms of water. The length attained by the mature stipe seems to adjust itself to the depth of the water, mature specimens being frequently found in shallow water with the normal size of bulb and length of fronds, but with the stipe not exceeding 1 m. in length.

Nereocystis, as Frye and Setchell have observed, thrives in strong tideways. The writer has never found specimens of the plant growing in quiet water and has never seen any record of such being the case. Frye suggests that the moving water facilitates the exchange of gases. Submerged plants must, of course, get their oxygen for respiration and their carbon dioxide for the manufacture of carbohydrate food from the gases in the water. The need for these gases is great in the case of rapidly growing kelps and there is of course more gas in water disturbed by wind or tidal currents than there is in quiet water. As Frye observes, moving water facilitates gas exchange by carrying away that laden with evolved gases and lacking in the gases required.

A rocky bottom seems to be a necessary condition for the production of kelp beds in the Puget Sound region. The writer has never found this species attached to smooth stones such as *Cymathaere* fastens upon, but always to irregular pieces of rock. This agrees with the observation of Frye. Neither has he ever found it attached to other algae. Setchell has found *Nereocystis* attached to stones and in some cases to the stipes of *Pterygophora californica*. The distribution of the latter species is very limited in the region investigated by the writer of this paper. He found it in the vicinity of Neah Bay only. The writer has frequently found other plants depending upon *Nereocystis*, but has never found *Nereocystis* depending upon any other plant. *Costaria* is quite commonly found anchored to the holdfast of this plant, *Antithamnion* and other red algae and *Desmarestia* and other brown algae to its stipe and pneumatocyst. All of the species epiphytic upon *Nereocystis* in the Puget Sound region are weaker than it in both holdfast and stipe. *Pterygophora* has a much stronger stipe than *Nereocystis* has and it has a powerful holdfast. The writer has not had sufficient experience with this species to make a positive statement about the relative power of its holdfast as compared with that of *Nereocystis*.


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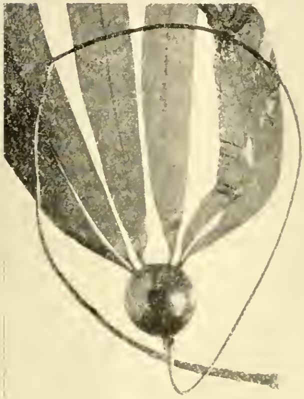
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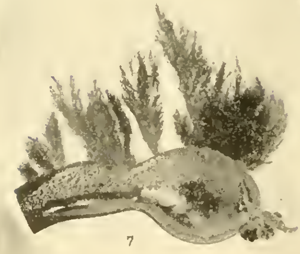
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Fig. 3 Holdfast of bladder kelp, showing dichotomous branching of hapteres and the disc-like structures formed on them where they come in contact with solid objects.

Fig. 4 Series of juvenile bladder kelps collected at Puget Sound Marine Station, July, 1911.

Fig. 5 A juvenile bladder kelp just beginning to form its pneumatocyst.

Fig. 6 A young bladder kelp showing basal origin of the splitting of the laminal region into numerous laminae.

Fig. 7 Part of pneumatocyst of bladder kelp with a filamentous brown alga epiphytic upon it.

Fig. 8 Part of stipe of bladder kelp with *Antithamnion* epithytic upon it. Photographs by S. M. Zeller.

Since the bulb of mature specimens of this plant is always at the surface of the water, the fronds in which the photosynthetic tissue is evidently located are kept just beneath the surface in a situation favorable for the maximum amount of light that could be obtained without exposing the fronds to the drying influence of the air. The penetration of light far into the water is a factor in the distribution of this species only during its very young stages.

The combination then of a rocky bottom, a strong tideway and suitable depth of water is necessary for the production of a large *Nereocystis* bed. The combination of these conditions is most frequently found on ledges of rock along the shore. There is a narrow fringe of kelp along a large part of the shore line of the San Juan Islands. Much of this fringe does not exceed 8 m. in width, but at Kanaka Bay on the west side of San Juan Island and at Iceberg Point at the southern end of Lopez Island the beds broaden to 100 m. or more. Navigators in this region feel safe in running their boats close to the outer edge of the kelp beds, knowing that where the kelp ceases to be seen it means a sudden increase in the depth of the water. In the case of the Smith Island bed the ledge is so extensive that the bed is about 1800 m. square. The beds are extensive also along the American shore of the strait of Juan de Fuca, especially in the vicinity of Cape Flattery and Neah Bay where they attain a width of 200 m. in some places.

Not all the kelp beds, however, are found along the shore. A shoal with a rocky surface frequently furnishes the conditions for the production of a large bed. Examples of this are found on Dennis shoal west of Allan Island, on West bank north of Orcas Island, and on the shoals north of Patos Island and on those north of Sucia Island. Dall[6] reported in 1875 that there was a bed of "bull-head kelp" (*Nereocystis?*) 25 square miles in extent on a shoal in the open sea north east of St. George Island in the Bering sea. Nearly all of the *Nereocystis* beds of the Puget Sound region are what the foresters would call a "pure stand," but in the vicinity of Neah Bay some of the beds are mixed with *Egregia menziesii* and *Macrocystis pyrifera* on the side toward the shores.

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[6] Dall, W. H. Arctic marine vegetation. Nature, 12: 166. 1875.

The Alden banks in the Strait of Georgia north of the San Juan Islands illustrate an unexplained condition in regard to kelps. Throughout a large area, occasional clusters of kelps are found. There are from 5 to 25 individuals in a cluster and they are much entangled, as if their holdfasts were all very close together. A somewhat similar condition is found at the south end of Guemmes Island near Anacortes, Washington, and along the shore near New Dungeness, Washington. The clustering is not so evident in the two latter cases as in the first but in all of them the individual kelps are vigorous enough but there are few of them. It would seem that in these cases the tidal conditions are right but either the depth of the water or the lack of suitable rocks for anchorage may be the inhibiting factor. In case it should be merely the absence of rocks, it seems possible that the yield might be increased by adding rocks. A more intensive study of the conditions in these beds is necessary before absolute conclusions can be drawn.

In arriving at an estimate of the tonnage of the annual crop of kelp in the region studied, the writer first estimated the number of plants per square foot in the beds by placing a light wooden frame 4 feet square down upon the beds and counting the plants whose bulbs were included. By doing this repeatedly, he estimated that the thicker beds contained 1.25 plants per square foot. Fairly dense beds vary from this down to 0.75 plants per square foot. The weight of the individual plants was the next consideration. It was found that mature kelp plants fresh from the water weigh from 18 to 35 pounds. Knowing then the weight of the plants and the number of plants per unit of area, one has but to determine or estimate accurately, the length and width of a bed in order to estimate more or less accurately the number of tons of kelp present. By the above method the writer has estimated the annual crop of kelp of the Puget Sound region including the American shore of the strait of Juan de Fuca to be 210,000 tons. About one-half of this is in the one bed at Smith Island. Since the plant is for practical purposes an annual and its spores are matured in June, July and August, it seems that the crop might be harvested after July 15 without interfering with the next year's crop.

TABLE 1

The results of chemical analyses of air-dried kelps. The material was collected by the writer, and the analyses were made by Dr. J. W. Turrentine of the Bureau of Soils.

	ORGANIC MATTER	IODINE	ASH	NaCl	KCl
Nereocystis luetkeana, sample 1.	41.87	0.08	2.30	15.30	40.60
Nereocystis luetkeana, sample 2.	46.20	0.17	2.50	14.90	36.40
Nereocystis luetkeana, sample 3.	55.30	0.15	4.30	14.80	25.60
Macrocystis pyrifera, sample 1 . .	51.50	0.20	16.00	1.50	31.00
Macrocystis pyrifera, sample 2 . .	49.60	0.22	19.20	7.30	22.10

When these kelps are taken from the water and spread out so that they will not decay, a whitish coating of salts is formed on the surface. This is true of both fronds and stipes. The air-dried material including these salts weighs from 3 to 6 per cent of the weight of the plant when fresh from the water. Dr. Frank K. Cameron reports that the dried material has been found on analysis to contain from 25 to 40 per cent of potassium chloride, which he values at $40 per ton. This would mean that the value of the annual kelp crop of the Puget Sound region is $100,000 or over for fertilizer purposes alone. This takes no account of iodine or other by-products. *Nereocystis* has frequently been used locally by gardeners of the region for fertilizer and has given good results. A fertilizer factory is now in operation at San Diego, California, using *Macrocystis pyrifera* as raw material. Two Seattle men hold a patent on a process for manufacturing from *Nereocystis luetkeana* substitutes for preserved citron, orange peel, lemon peel and other candied and preserved products. The writer[7] has elsewhere described a method of rendering the fronds of this plant leathery and the stipe rope-like, but there has not so far been found any use for the material so treated other than that of classroom demonstration of the form of the plant.

The Indians of the Pacific Coast of North America found several uses for the bladder kelp. The Alaska Indians formerly made fish

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[7] Rigg, G. B. A method of preparing the larger algae. The Plant World, 8: 202. 1911.

lines of the long cord-like stipe by soaking them in fish oil and manipulating them to render them pliable. Bottles to contain the oil were made from the bulb and the adjacent hollow part of the stem by the same process. It is reported that the Indians in the San Juan Islands formerly prepared salt for use in food by spreading the fronds of this plant on clean logs and collecting the salt that effloresced on the surface of these fronds. The hollow part of the stipe was used by Alaska Indians as a worm in the process of distilling "hoochenoo," a dark-colored poisonous drink. Headache is cured by the Indians in Sitka by placing the smaller end of one of these tubes in the ear and the other against a hot stone to generate steam. The Makah Indians at Neah Bay still use the split bulb of this plant for application in cases of caked breasts. It seems to be soothing and antiseptic. The Indians formerly used the hollow portion of this plant to give the illusion that a voice was speaking from the fire. The smaller end of the hollow portion was concealed near the fire while an Indian hidden behind a convenient rock or bush spoke into the large end.

Considering the abundance of the seaweeds in Puget Sound in connection with the large use that the Japanese make of their seaweeds, the question naturally arises as to whether there is a potential kelp industry here. As the first step toward answering this question we must consider how far our conditions are similar to those in Japan. The population in the Pacific Northwest is not over dense and there is no congestion of population on the seashore. Americans certainly could not be advised to take up the slow and painstaking work of gathering seaweeds by hand and preparing them for food, and the Japanese who have come to our shores have shown no disposition to do so. If a kelp industry is to be developed in the Puget Sound region, it must utilize a plant whose abundance and situation will permit it to be harvested in large quantities by labor-saving devices. There is but one such plant in the region,—the bladder kelp.

BOOKS AND CURRENT LITERATURE

Forests of the Philippines.—Whitford has embodied his further work on the Philippine forests in a report[1] which is of considerable interest to the botanist and of great value to the forester, at the same time that it is of general interest as giving specific information on the extent of the most valuable natural resource of our largest colonial possession. The first part of the report, Forest Types and Products, describes the principal types of forest in the Philippines, the uses of the various woods and their physical properties, and gives considerable practical information about logging and milling methods, labor conditions, and the like. A statement of the classification of lands shows that virgin forests, 40,000 square miles in extent, occupies one-third of the area of the archipelago, and that virgin and second growth forests together occupy nearly one half. An accompanying map indicates the location of these areas.

The virgin forests are classified under ten types, five of which are dominated by species of the Dipterocarpaceae, and together make up 75 per cent of the total virgin forest area. The largest trees of these forests are said to resemble *Liriodendron tulipifera* in form and size. In the Lauan type of forest the stand of timber, according to Whitford's surveys, is 42,900 board feet per acre. The Lauan forest and two of the other Dipterocarp types occupy those portions of the low coastal plains which have a well-distributed rainfall. The Lauan-Apitong type is found in somewhat drier regions at low elevation, and has a considerable deciduous element in its make-up. The Tanguile-Oak type is evergreen and is found from 1200 to 2700 feet elevation, under conditions of more equable rainfall than the lowland forests. The types of forest not characterised by Dipterocarps are: the Molave (*Vitex*) type, occurring in limestone regions; the Pine type, occupying the plateau of northern Luzon and characterised by *Pinus insularis*; the Mangrove and Beach types, occupying the coast; and the Mossy type, occurring on the highest mountain ridges, which is partially made up of the conifers *Dacrydium* and *Podocarpus*.

The second part of the report, The Principal Forest Trees, illustrates

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[1] Whitford, H. N., The Forests of the Philippines. Bull. 10, Bureau of Forestry. Part 1, pp. 94, pls. 28, map; Part 2, pp. 113, pls. 103; Manila, 1911.

and describes over one hundred of the commonest trees. The descriptions are confined to the characters with which a forester comes in contact, which makes them many times more valuable in a tropical forest than descriptions based on flowers and fruit would be. There is also a key to these species based on vegetative characters.

The work of Whitford and his associates is laying a broad foundation for the future forestry policy of the Philippines. To Major Ahern, Director of Forestry, is due great credit for his broad-mindedness in encouraging forest work which has scientific value,—which is merely saying that it has fundamental rather than purely superficial practical value,—and for his far-sightedness in wishing to have these foundations laid in time to secure a conservative management of the immense forest resources of the islands.—F. S.

Poisonous Plants.—Pammel's compendious treatise on poisonous plants[1] presents practically all that is known about the poisonous plants of the United States, if not of the world, because it includes a description of many foreign species that have been in cultivation in the United States. The first part deals with such topics as poisons and statistics on poisons, bacterial poisons, dematitis, forage poisoning, ergotism, aspergillosis, poisoning from fungi, equisetosis, locoism, lupinosis, fish and arrow poisons, hydrocyanic poisoning, toxalbumins, poisoning from opium, poisoning from flowers, poisoning from honey, mechanical injuries, classification of poisons, symptoms, antidotes, the production of poison in plants, algae in water supplies, a catalogue of the more important poisonous plants of the United States and Canada, chemistry of alkaloids, glucosides and so forth. With even greater completeness of detail, and with the aid of numerous figures, the author in Part 2 deals with the poisonous plants arranged systematically according to natural families. The reviewer believes that a number of small families of plants have unfortunately been included although they hardly merit treatment in a book bearing this title. Considering the stupendous amount of work involved, however, the author may be excused the occasional padding. The work closes with a catalogue and bibliography of poisonous plants.—John W. Harshberger.

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[1] Pammel, L. H., A Manual of Poisonous Plants, chiefly of Eastern North America, with brief notes on Economic and Medicinal Plants, and numerous illustrations. Part 1, pp. vi +150, 1910; Part 2, pp. v+151–977, figs. 458, 1911.

NOTES AND COMMENT

Professor Ernst Bessey's interesting account of the angiospermous areas known as "hammocks" within the pinelands of southern Florida (Plant World, **14**:268–277) recalls a theory of their origin which I formed the last time I traversed this region, which was in coming north from a cruise among the Florida Keys with Dr. Howe in the spring of 1909, on a train of the Florida East Coast Railroad. We had been talking about mangroves and their function as land-builders, a subject which has interested us on many occasions, and as the train swung away from the coast, crossing the "prairies" toward the pineland margin south of Homestead, we remarked on the gradual substitution of mangrove clumps by mixed mangrove and other hardwood shrubs and trees, the mangroves extending to about the limit of saline influence. I formed the impression at that time of the possible parallelism of these hardwood islands in the wide marshy stretches with the hammocks in the pinelands. An elevation of the land of no more than two or three meters would so drain it as to make the wet ground habitable by upland plants after the salinity had been reduced by leaching, and during this doubtless gradual elevation and leaching, the islands would provide a suitable nidus for the establishment of more hardwood trees and shrubs and the various other elements which go to make up the hammock association, while the pines would be free to spread over the wider prairie areas. The upland areas now occupied by pinelands and hammocks have doubtless been elevated to their present position within a relatively recent geologic time. Former studies of the hammocks with Professor Rolfs had brought me to Professor Bessey's conclusion that the subsoil has little or nothing to do with the striking floral differentiation of hammock and pineland, it being the aeolian or coral-rock bottom of all south Florida, so far as we could ascertain, and I then suspected an ancient origin. Professor Bessey's paper has brought the topic again to mind and I present the above theory as a contribution to the discussion. Will Professor Bessey print such evidence as he has of the increase in size of the hammocks? I know that some are said to cover more ground than they formerly did, but my visits to the region have been of such short duration that I could not satisfy myself of the truth of the proposition.

In the area of Caribbean pine in western Cuba I have not seen anything quite similar to a Florida hammock, the hardwood species there growing for the most part along water courses, but the land is mostly considerably more elevated than that of South Florida. However, the associations are nearly repeated on the larger Bahamian islands inhabited by the pine, where the land is often of considerable elevation, though the sharp demarcation we see in south Florida is not always so evident; in the Bahamas, the hammocks are called "coppets" or "coppices" and they contain many of the Florida hammock species with many others. The mangrove-prairie association is there quite paralleled by regions known as "swash."—N. L. Britton.

Every botanical laboratory should possess a copy of Henley's Twentieth Century Book of Recipes, Formulas, and Processes (Henley Publishing Company, New York, $3). The book contains over ten thousand recipes, trade secrets, and descriptions of processes used in the arts and industries, among which are valuable suggestions relative to many of the operations which every scientific teacher or investigator finds at one time or another to be essential to his work.

THE QUEST OF PHYLETIC LINES

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For over half a century the Darwinian aspect of descent has been before the mind of biologists, and though more recent developments of method and thought may have tended to modify or extend our conception of the mechanism of evolution, still the central problem remains the same, viz., to understand how the various living things we see came to be what they are, and where they are. It is natural that such problems should take a strong hold on active intellects—they engender keen enthusiasm, and so strong may this be that it is apt at times to outrun the cooler canons of criticism. One sees a theory promulgated, and the enthusiast may accept it with a sense of assurance that it is the true interpretation of the facts which it seems to cover. The detached cynic, regarding it with cooler and more critical gaze, may probably hold aloof, with a sense that the explanation is too simple and too direct, or that the substratum of fact is insufficient to bear the weight of the superstructure of theory.

Seeing such diverse estimates made, and strongly upheld or, it may be, repudiated—estimates that are referable in their origin sometimes to the temperament as much as to the intellect of their respective adherents—suggests a revision of the ground work upon which such opinions should rest. Whether our temperament be sanguine or phlegmatic, and in relation to it our arguments tend to be constructive or destructive, it is well to see clearly the foundations on which we build. Accordingly it seems to be worth while to examine what are the fundamental data upon which so many are busily engaged in constructing the modern phylogeny of the plant kingdom.

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The first datum is the presence living upon the earth of individuals illustrating numerous plant forms which appear distinct by character and by genesis. A comparison of those plant forms one with another shows underlying similarities. Where these are greater than their points of difference they are held to be indications of natural affinity, and a general theory of evolution based on such comparisons has long been entertained as accounting for their origin. But it is necessary to remember always that this is not, and probably never can be more than a working hypothesis. Secondly, within narrow limits of variation like produces like. Hence the inference is justified that, in broad lines, what holds for the present has also been the rule for the past. It is accordingly a general view that evolution has been slow, and has progressed by relatively gradual steps of divergence of offspring from the progenitors. Thirdly, though certain of the forms we find now living graduate by very gentle steps one into another, and thus form natural groups or families, others are dissociated and relatively isolated. In extreme cases a genus such as *Isoetes,* or a single species such as *Welwitschia mirabilis* is thus recognized as monotypic. Such forms provide the most obvious problems of evolution, though they are also the most difficult of solution. For their very isolation, suggests that many of the gradual evolutionary steps have been lost, and that the sequence of living forms reflects the past history very imperfectly. Fourthly, the geological strata of successive ages have yielded evidence of a succession of fossil forms, comparable in varying degree with those of the living flora. From these some positive indication has been derived as to the relative ages of certain of the living types. These indications serve as suggestions as well as checks upon the efforts of comparative morphology—that branch of the science which proceeds primarily from the study of organisms now living.

It must be obvious to those who study either living forms or fossils, or what is better, to those who study both, that the record from either source, or from both combined, is very incomplete. The frequent existence of monotypic forms is a pregnant fact, and still more their prevalence among those which comparison, as well as the fossil record, teaches us were relatively early. Thus the evolutionary history is most imperfect in its earliest chapters. Nevertheless the question of origin by descent, and of the phyletic relationships of these isolated and at the same time primitive forms, has fastened itself upon the minds of our contemporaries with a singular insistence. Perhaps the very difficulties which such problems present are a source of their special attraction. The result has been voluminous writing, in which argument outweighs fact, and criticism is often conducted without any clear conception of what the canons of criticism should be.

The Archegoniate forms have been the central field of phyletic discussion just as the Low Countries were the fighting ground in European wars. I do not propose here to allude in detail to any of those various and divergent views relating to them and to their place in descent, which have found partial or it may be general acceptance in recent times, but to turn to opinions which have been discarded. It will be possible to illustrate the difficulties and fallacies which attend such discussions through the medium of opinions which at their time claimed wide attention, or even general adherence, but are now superseded. Useful lessons may thus be learned, which will find their application in criticism of phyletic study as it now stands.

Those whose botanical experience dates back to the seventies of the last century will remember the position as almost axiomatic, that the Leptosporangiate Ferns were the most primitive Vascular Plants, and that all the rest were to be referred to that source. Treatises still exist in print explaining the steps of such derivation, and suggesting on a basis of comparison how the Eusporangiate state originated from the Leptosporangiate, and how by condensation of the fern-like shoot even the Psilotaceae and Lycopods might be arrived at. If we analyse the steps leading to such conclusions in the light of later experience it is possible to find the flaws in the argument; but in doing so there is no need to sacrifice respect for their authors, who were often the leading thinkers of their time. The prime error in the present instance was a very natural *assumption* that those propagative organs which are simplest in structure were the earliest in descent. The delicate sporangium of a *Scolopendrium* or of a *Davallia*, with its long stalk composed of a single row of cells—structurally so like a hair bearing a terminal gland—seemed the natural predecessor of the more massive, and short stalked, or even sunken sporangia of the Marattiaceae or Ophioglossaceae. The analogy of the simpler superior as compared with the more complex inferior ovary of Flowering Plants doubtless lent colour to the conception that this progression had been a real one. A further error was the neglect of collateral checks upon the opinion thus assumed. If it were true the Leptosporangiate Ferns should preponderate in the Primary Rocks, and the Eusporangiate Ferns should be characteristic of higher horizons. But the observations of Stur and others showed that the converse was actually the case. The revolt against the position thus based primarily on assumption, and insufficiently checked by collateral lines of comparison, was initiated by Campbell.[1] Probably no paper of like brevity has ever had a more far-reaching effect than this in correcting erroneous views. Once the basal assumption is swept away, and the eusporangiate sporangium accepted as relatively primitive, there appears no need to refer the sporangia of the Equisetales or Lycopodiales to that simple origin typified by the Leptosporangiate Ferns. In fact the way lies open to the polyphyletic origin of the Pteridophyta which is now so generally recognised, and supported on so many lines of more recently acquired evidence.

A second view now discarded, which at the time received general attention, though never a very general acceptance, was the phyletic origin of the Hymenophyllaceae, as the simplest Ferns, from the higher Mosses. It was suggested by Prantl that the sorus of a *Trichomanes* was the correlative of a moss sporogonium, that the indusium represented the sporogonial wall, and the receptacle the columella, while the spore-sac was the correlative of the sporangia seated upon it. This hypothesis received an apparent support in the delicacy of texture of the Hymenophyllaceae, which was held as primitive, and in the filamentous prothallus of *Trichomanes*, which appeared to correspond to the protonema of the Moss.

The fallacies here involved are more complex than in the former case, but again assumption takes a prominent part. In the

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[1] Bot. Gaz., January, 1890.

first place it was assumed that similarity of vegetative texture implies a common origin, allowance not being made for the possibility of parallel development. It is now widely held that the filmy condition of the Hymenophyllaceae is a result of specialisation to a moist habitat, which finds its correlative in many distinct phyletic lines. Secondly, it was assumed that the parallel between sorus and sporogonium is a real one, though there is an entire absence of any intermediate steps to show that such a transformation as that assumed ever took place. Such a demonstration was especially necessary where the transformation which was assumed was so far reaching and fundamental. It is true that the relative positions of the parts named were in correspondence, and that their functions were also alike. But the presumed change involved the origin of the sporangia, which in Ferns are always superficial and of very specialised structure, from the spore-sac which is of internal origin, and shows no sign of similarity to the Fern sporangia beyond the production of spores. To render the suggestion even plausible some structural indication of the steps of the transition in allied forms was essentially necessary. But this evidence was not brought. The hypothesis failed through the absence of any chain of intermediate conditions between the two widely divergent types compared. The modern view is of course that there is no direct phyletic relationship between the Hymenophyllaceae and the Mosses: and that the similarities, such as they are, are the result of adaptation of two distinct spore-bearing phyla to conditions of life which have been similar in their leading traits.

A third example is seen in the anatomical comparison between the stele of certain species of *Lycopodium*, such as *L. clavatum*, and the polystelic state seen in certain species of *Selaginella*, such as *S. Wildenovii*. It was suggested, and widely held until quite recent times, that the more or less distinctly separate xylem-plates of the former resulted from the lateral fusion of steles originally separate as in the latter type. As long as the comparison is based upon isolated transverse sections, the suggestion appears reasonable enough. But the time is gone past for such comparisons as these, and conclusions must be tested upon a much broader basis of fact and of reasoning.

In the first place *Lycopodium* belongs to the Eligulate Lycopodiales, which are, and appear always to have been homosporous. *Selaginella* belongs to the Ligulate Lycopodiales, which are, and from Palæozoic times have certainly been heterosporous. There is good reason to believe that the two phyla have been distinct from one another from a very early period, and a comparison of their living representatives, together with the evidence of their fossil history, leads to a different conclusion from that above stated. Taking the Ligulate series, comparison of those now living indicates that the radial upright types which centre round *S. spinulosa* are relatively primitive, while those with dorsiventrally flattened shoots are derivative. It is in some of the latter only that the polystelic state, which was the basis for comparison with *Lycopodium*, exists. It is thus seen to be probably a late and derivative state. The species of the type of *S. spinulosa* have a single protostele corresponding in its main features to that of the early Ligulate fossils, and this supports the comparative conclusion arrived at on the evidence of the fossils. From both sources the conclusion is thus attained that the primitive state was protostelic, and the polystelic state seen in the dorsiventral species is relatively late and derivative. Turning to the Eligulate series, the evidence is less complete though still sufficient. A comparison of living species of *Lycopodium* indicates that those which are in general features most primitive, such as the upright types associated with *Lycopodium Selago*, have a relatively simple stele, with a continuous xylem-tract, which may, however, be variously lobed as seen in transverse section. The types where the xylem appears in distinct plates are those which on general lines of comparison are held to be more differentiated and advanced, as is the case in *L. clavatum*. Thus in both Ligulate and Eligulate Lycopodiales the vascular structure is referable on a basis of broad comparison to the protostelic state, with a simple and solid xylem-core. Both of these apparently distinct phyletic lines have proceeded to more elaborate structures, in the former case with distinct steles, in the latter with more or less distinct xylem-plates within the stele. There appears to have been a parallel response to a need for elaboration, which has led to the states exemplified respectively by *Selaginella Willdenovii* and *Lycopodium clavatum.* Thus the error in comparing these isolated types on the basis of mere transverse sections is that common one of comparing distal phyletic results, which have been achieved along parallel lines of advance. The similarities were not original but adaptive. The error is in fact essentially similar to that in the comparison of the moss sporogonium with the Hymenophyllaceous sorus. It is in both cases to be corrected by a broader comparison which brings to light the probable phyletic lines and shows that the types compared are distal, and result from adaption along parallel lines, rather than indications of phyletic similarity.

Allusion may here be made to another opinion widely held in earlier decades, which had its relation to phyletic views, viz. the reference of sporangia to various categories of vegetative organs. Thus the sporangium of a Leptosporangiate Fern was held to be a metamorphosed hair, because of its origin from a single cell: Eusporangiate sporangia were regarded commonly as emergences: some ovules were held to represent pinnae or leaves, or even vegetative buds, while occasionally pollen sacs or ovules were regarded as being of axial nature. Such reference of propagative organs to categories of vegetative parts was a natural consequence of the pursuance of Goethe's theory of metamorphosis into its ultimate detail. So long as our study is one of mere comparison of the objective facts, as exemplified in organisms now living, and without any consideration of their origin by descent, such views may serve. But plainly they are inconsistent with current beliefs as to descent. Throughout the whole history propagative organs must have taken their place in each completed cycle of life. There is every reason to believe that organs of vegetation will have been evolved *pari passu* with propagative organs, and there is no reason to think that the latter have been in any sense phyletically the result of metamorphosis of the former, though it is possible that the converse may have actually occurred. The source of the whole difficulty presented by the theory of Goethe, and its derivative sub-theories, lay in this general fact: that they were pre-evolutionary, or frankly non-evolutionary. Otherwise they could not have left out of consideration this necessary fact of descent, that propagative organs must have appeared in each completed cycle. Propagative organs are not things formed *de novo* in descent by transformation of some preëxistent vegetative structure—they are organs *sui generis.* It was Goebel who first realised this, and his statement of the principle for sporangia in 1880 may be held to have constituted an essential step forward in modern morphology. For us at present the chief interest lies in this: that the theory of metamorphosis left out of account this essential feature of descent, that the propagative organs are not afterthoughts, but recur as an incident in every completed life cycle.

The foregoing paragraphs are not written in any frame of censorious superiority. The object has been to learn from experience of the past the methods to be used in the present and the future in the quest for phyletic relations, and we are now in a position to recognise some at least of the sources of weakness or of strength in any phyletic view that may be promulgated. It is the absence of direct evidence, due to the imperfection of the fossil record on the one hand, and to the survival of so few representatives of earlier evolutionary steps on the other, that has made it thus necessary to fall back upon elaborate weighing of evidence, and has left the conclusions so much matters of opinion rather than of actual demonstration. But clearly seeing that this is so, we shall now recognise the following sources of weakness under which views as to descent are liable to suffer.

1. *Assumption.* Few realise as they write how largely assumption figures in their arguments. A careful analysis of the lines of reasoning is often necessary to detect where an assumption lies. Unfortunately such analysis has often to be made by a critic instead of by the author himself. We have seen an instance in the assumption that all that is simple is primitive, and the consequent conclusion that the Leptosporangiate state preceded the Eusporangiate. It is well to bear constantly in mind that the simplicity of reduction is very prevalent. This is much more generally recognized now than formerly. There is even a converse danger, of which modern instances could be quoted, of assuming reduction in order to explain facts that are otherwise

difficult. All such assumptions must be submitted to the check of physiological probability, while their risk as pure assumptions may be diminished, or even removed, by the recognition of intermediate steps.

2. *The neglect of collateral checks.* In order to place a phyletic view on a footing of reasonable probability it will not suffice to advance a single train of facts. The fossil record was not taken into account in checking the assumption that the Leptosporangiate Ferns were the earliest, nor in assuming that the *Lycopodium* stele was the result of the fusion of the numerous steles of *Selaginella*. These conclusions fell away so soon as the palaeontological check was applied. It is not uncommon, especially in the work of beginners, to see broad phyletic conclusions drawn upon the basis of merely anatomical facts, or of details of a sporangium, or of the contents of an embryo-sac, without any reference to the broader features or history of the organisms compared. All such conclusions must be held as provisional, and open to revision whenever a broader basis of comparison is adopted.

3. *Neglect of the fact that intermediate steps between the organisms compared are not known.* The prominent example of a comparison wrecked on this ground is that of the Hymenophyllaceae and the Mosses. No evidence of any intermediate step between these divergent types could be produced. On the other hand a line of probability emerges from the detailed study respectively of the Musci and of the Filicales, that the characters which formed the basis of the comparison are consequences of specialisation along parallel lines. This mode of reasoning is the source of many of the fanciful and even divergent opinions which have from time to time been promulgated with regard to the morphology of the distinct phyla of Pteridophytes. It is in the first instance assumed that they must conform to a certain structural mould. It is forgotten that intermediate steps do not now exist between them, and the attempt is then made to force the divergent types into the single assumed morphological mould. This was also the method long pursued in the comparative morphology of the Angiospermic flower.

4. *The use of single characters for purposes of comparison.* This

is perhaps the most prevalent source of fallacious conclusion in dealing with organic life. It is the rock upon which the Linnaean System split. But how many are there today who, while they would speak with scornful superiority of that system as rightly displaced by the so-called Natural System, would straightway set themselves to write down comparative arguments based solely upon some minor detail of internal anatomy, exhibited in some isolated and relatively primitive organism? None have erred in this respect more frequently than the anatomists. The exact position of protoxylem will often weigh more with a writer (who could not tell you what circumstances determine it) than the whole sum of characters of the external form of the organism. The corrective to this perilous method is to be found in the tracing of parallels in as many characters as possible—in fact the adoption of exactly the same practice in the modern comparative study as was introduced by the founders of the Natural System of classification of Flowering Plants.

Having thus recognized some of the sources of weakness which are apt to detract from the worth and permanence of phyletic comparisons, we may in conclusion state positively what are those factors which would conduce to correctness, and therefore permanence in the quest of lines of descent. In the first place we must be certain that we are dealing with *phyletic unities.* Parallel development is not known to have resulted so often from similar adaptations in distinct lines of evolution that it is necessary to be certain that the forms compared, as illustrating a supposed progression are really akin. The tests of this will consist in the comparison on the basis of as many characters as possible, and in the recognition in as continuous sequences as possible of intermediate steps between extreme forms. Towards the latter the fossil record with its sequence of horizons may be expected to supply the most direct aid, especially in the case of relatively primitive types. In any case the position will be the more assured in proportion to the number of related species. If these can, on adequate investigation, be themselves ranged into short series, showing by parallel progression of several distinct characters that they constitute true sequences, it may then become possible to link them together into more extensive evolutionary series. In each case the possibility of the series being progressive or retrogressive or, it may be, even divergent from a central point, must be kept in mind, and the line of criticism from physiological probability be constantly applied. An error which is very frequently made is to neglect the comparative study of species within a genus. But it is only in this way that the short series above referred to can be constructed, and such short series be ranged in any probable relation one to another. A general, or *generic* conception of the organisms compared will not suffice—a *specific* knowledge is necessary for trustworthy comparisons. Or in other words, the phyletic comparison should start upon the basis of specific knowledge. It is this deficiency which underlies much of the modern speculation as to the phyletic origin of Angiosperms. We shall anticipate that those who have made the Angiosperms their special study, while being adequately informed of the fossil data, will be more likely to give a trustworthy solution of this phyletic riddle than the students of fossils whose knowledge of the living flora of Angiosperms is rarely wide and at the same time specific.

It has been already pointed out how deficient is the early fossil record, and how isolated are those plant types which we have reason to regard as the most primitive. Such survivals are, as a rule, poor in species, or may even be represented by only one. This makes comparison still more difficult. But turning from these, in reference to which comparative morphology is sometimes little better than guess-work, there are certain large groups in which the comparison is susceptible of more scientific treatment. The factors which lead to this more happy result are: first, the representation of the phylum by numerous living families and genera, with a good spread of species; secondly, that the characters on which the classification is based shall be as various as possible; thirdly, the fossil origin should not be too remote, and the record should extend through as long a sequence of geological horizons as possible. Given these conditions, an adequate study of the representatives, conducted specifically, and based primarily on the living forms, with the data from the fossils serving as a check, should lead to sound views as to descent within the phylum, though not necessarily to any demonstration of its prime origin. When we look round upon the great divisions of the plant kingdom, it is at once realised how rarely these conditions are fully met. The Algae and Fungi have virtually no consecutive fossil record known as yet, while the deficiency of their anatomical characters throws comparison chiefly upon their organs of propagation: so that notwithstanding the wealth of species their phyletic study presents difficulties. The Liverworts and Mosses are alike without any reliable Palæontology. The former present more hopeful characters for comparison of living forms than the latter, for these suffer from their relatively dead level of uniformity, except in characters that are almost minimal. The Lycopods and Equiseta were both of exceedingly ancient origin, antedating the palæontological record in most of their salient characters. Nevertheless the fair representation of living species both of *Lycopodium* and *Selaginella* gives a fair opening for comparative study, which has not been neglected. The Gymnospermic state was already established in times prior to the earliest dependable facts of palæontology, and though the fossil record helps in many points, still the gaps in it, as well as the isolation of many of the living types have made their phyletic study full of problems. And lastly the Angiosperms, with their plethora of living representatives, have so recent and so imperfect a fossil record that, in face of the lack of settled canons of critical treatment of those living, their phyletic arrangement is still chaotic, and views of their descent very divergent.

None of these large divisions of the plant kingdom answer the requirements stated above so fully as do the Filicales. We find them to have a fossil record which is hardly matched in its extent and in its consecutive character. They are represented at the present day by a wealth of species, grouped in well-defined genera and families. They show a great variety of characters, which are a suitable basis for comparison, while the fossil record shows certain of them to have been progressive through the ages. Putting on one side the Eusporangiate types (whose isolation and paucity of species, as well as the ancient origin of some of them, render them problematical in their phyletic relation), it may be said that the Leptosporangiate Ferns are of all Vascular Plants those to which the canons of phyletic treatment may be most hopefully applied. Their origin is not entirely lost in the antiquity of their story. They present a variety of characters of external form and habit, of anatomy, of sorus and sporangium, of prothallus and sexual organs, which can be traced, and their parallelism compared. The results can be checked by reference to fossils of successive horizons, and lastly, since the several types are for the most part adequately represented by living species, the check of physiological probability can be applied, and even experimentally tested. Though the genetic relations appear here to be as involved as in any well represented division of plants, still in combing those relations out into true phyletic sequences the work may be conducted with as high hopes, and as truly scientific a foundation as in any section of the vegetable kingdom. This is still far from being accomplished. But if it be pursued in a broad scientific spirit, the result will probably serve as an object lesson, which may be applied in laying down the canons of comparison for other and still more difficult series of plants.

COLD AIR DRAINAGE

FORREST SHREVE

The Desert Laboratory, Tucson, Arizona

The arid regions of the earth exhibit great daily ranges of temperature by reason of conditions which permit a rapid heating of the soil by day and a correspondingly rapid cooling through radiation at night. The chief conditions which permit these rapid changes are the absence of a heavy plant cover, the predominance of sands and stones, and the usual absence of a nocturnal cloud blanket. The rapidity of nocturnal radiation in the desert is responsible for the phenomenon known as inversion of temperature, which is at once a cause and an effect of cold air drainage. Inversions of temperature in the free air have been made known through observations on the Eiffel Tower in Paris and through kite observations at the Blue Hill Observatory. They have also been observed in mountain valleys, particularly in the Alps. Their importance to vegetation was first pointed out by Kerner,[1] and their pronounced character in arid regions as related to vegetation was first remarked by MacDougal[2] for the vicinity of Flagstaff, Arizona. Any thermometrical instrumentation carried out in the desert must be made with strict heed to the local conditions of cold air drainage, and the comparison of nocturnal or minimum temperatures from several stations must be made with a full knowledge of their topographic site.

During the past year the writer has been attempting, in connection with other instrumentation, to determine the normal

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[1] Kerner, A., Die Entstehung relative hohen Lufttemperaturen in der Mittelhöhe der Thalbecken der Alpen im Spätherbste und Winter. Zeitschr. f. Meteorol., 11: 1–13, 1876.

[2] MacDougal, D. T., Influence of inversions of temperature, ascending and descending currents of air, upon distribution. Biol. Lectures, Mar. Biol. Lab., Woods Holl, 1899. Boston, 1900.

temperature gradient of the Santa Catalina mountains, in southern Arizona. In this work it has been necessary to know the extent to which cold air drainage modifies and locally reverses the normal fall of temperature encountered with increase of altitude. The results secured afford fresh evidence of the magnitude of this chimenal factor, which is capable of causing a variation in the altitudinal limits of species and in the chronology of their seasonal activities, in relation to the topographic site which they occupy. It is the hope of the writer that similar observations in other regions will be made, and that other workers will bring forth any evidence they may have as to the influence of cold air drainage conditions on the distribution of plants.

The temperature data used consist of a series of fortnightly readings of the minimum at 4000, 6000, and 7000 feet (1220, 1830, and 2135 m.) in the Santa Catalina mountains, taken from April to October. The writer has also used a series of daily readings of the minimum at 8000 feet (2438 m.) for June, July and August, for which he is indebted to the hearty coöperation of Prof. J. G. Brown of the University of Arizona. As a basis of comparison for these mountain data, use has been made of the continuous thermograph record of the Desert Laboratory, the daily readings of minimum temperature taken at the Acclimatisation Laboratory by Mr. J. K. Breitenbecher in connection with Dr. W. L. Tower's work on the Leptinotarsid beetles, and kindly furnished by them, and also the record of the Arizona Experiment Station, furnished through the courtesy of Prof. Robert H. Forbes.

The mountain stations at 4000, 6000, and 7000 feet occupied the summits of ridges, while that at 8000 feet was in the bottom of a deep cañon. The Desert Laboratory occupies the narrow slope of a hill, 335 feet (102 m.) above the Santa Cruz flood plain, and the Acclimatisation Laboratory stands at the edge of this plain about 1000 yards (915 m.) away. The location of the two laboratories is comparable, then, to ridge and valley in the mountains, except that the mountain valleys are all much smaller than that of the Santa Cruz river, which is about 90 miles (145 km.) long and from 10 to 30 miles (16 to 49 km.) wide. It is to be expected that this large valley would give greater depressions of temperature due to cold air flow than would take place in the relatively small valleys and cañons of the mountains. The Arizona Experiment Station is located on the long, gentle mesa slope 85 feet (26 m.) above the flood plain and about 2700 yards (2470 m.) from its edge. The position of the Experiment Station is intermediate between the positions of the two laboratories, but nearer that of the Acclimatisation Laboratory.

A comparison of the monthly mean minima for the two laboratories and the Experiment Station for April to October, 1911, is shown in table 1. The differences between the means for the two laboratories are greatest in April, May, and June, during the driest and most cloudless months of the year, and fall to about one-half these differences during the rainy months of mid-summer. This indicates that the wetness of the soil, which affects its specific heat, and the frequent cloudiness of the nights in that season, which affects the rate of radiation, cause a greater difference between the different months of the year than do the general temperature differences of summer and winter. The temperatures of the Experiment Station lie consistently between those of the two laboratories and are nearer those of the Acclimatisation Laboratory, in harmony with its elevation.

TABLE 1

DATUM	APRIL	MAY	JUNE	JULY	AUGUST	SEPTEMBER	OCTOBER
Average monthly minimum temperature, Desert Laboratory	55.7	64.0	74.3	74.1	75.6	72.5	58.8
Average monthly minimum temperature, Acclimatisation Laboratory	41.9	46.2	59.9	66.4	66.8	63.6	48.0
Difference	13.8	17.8	14.4	7.7	8.8	8.9	10.8
Average monthly minimum temperature, Experiment Station	47.1	53.7	63.1	71.3	70.8	68.1	
Total monthly rainfall, Desert Laboratory	0.28	0.00	0.01	1.96	4.44	2.58	0.94
Number of days with 0.01 inch or more of rain, Desert Laboratory	1	0	1	8	12	7	2

The greatest difference between any of the daily readings for the two laboratories is 24°F. (13°C.) on May 21, and the least is 0.5°F. (0.2°C.), occurring on the night after a fall of 0.98 inch (2.5 cm.) of rain.

On several occasions readings of the minimum for the same night were made in the mountains on ridges and in the valleys 1000 feet below. These were taken in the humid mid-summer months, and the readings differed by from 4.5° to 8°F. (2.5° to 4.4°C.), which is to say they were not quite so great as the differences between the two laboratories. On an evening in late September a comparative set of temperature readings was taken on the floor of a cañon at 5000 feet elevation (1525 m.) and on the side of the cañon 100 feet (31 m.) above the floor. The first of the readings was taken five minutes before the sun set in the cañon.

TIME		FLOOR OF CAÑON	SIDE OF CAÑON	DIFFERENCE
September 24	4.30 p.m.	82	81	−1
	5.15 p.m.	72.5	79	6.5
	6.45 p.m.	68	76	8
	8.00 p.m.	64	72	8

In returning to the floor of the cañon after making each of the readings on the side, it was possible to notice an abrupt change of temperature at a particular level, which level became higher as the evening advanced. The floor of the cañon was filled with a veritable stream of cooled air with a very definite surface. At 4.30 the next morning the sky had become heavily overcast and the difference had fallen to 5°F. (2.7°C.). The greatest difference of temperature due to cold air drainage was, accordingly, nearly the same as the average apartness between the two laboratories during September. The evidence afforded by this series of readings and by the first autumnal effects of frost on vegetation in narrow cañons, shows that the stream of cold air is always a shallow one, probably never exceeding 60 feet (18 m.) in depth.

In order to determine a true temperature gradient for the mountains from the data in hand it is necessary to compare the three stations situated on ridges with the Desert Laboratory, and to compare separately the 8000 feet cañon station with the Acclimatisation Laboratory. The accompanying diagram (fig. 1) shows the two gradients thus obtained. A slight and indeterminable allowance for the greater operation of the cold air drainage depression at the Acclimatisation Laboratory, on account of the great size of the Santa Cruz drainage basin, would bring the two gradients more nearly into parallel. The rates of fall per 1000 feet of rise between the several stations are: Desert Laboratory to 4000 feet, 5.2°F. (0.95°C. per 100 m.); 4000 to 6000 feet, 2.8°F. (0.52°C. per 100 m.); 6000 to 7000 feet, 3.6°F. (0.67°C. per 100 m.); Acclimatisation Laboratory to 8000 feet, 2.2°F. (0.40°C. per 100 m.).

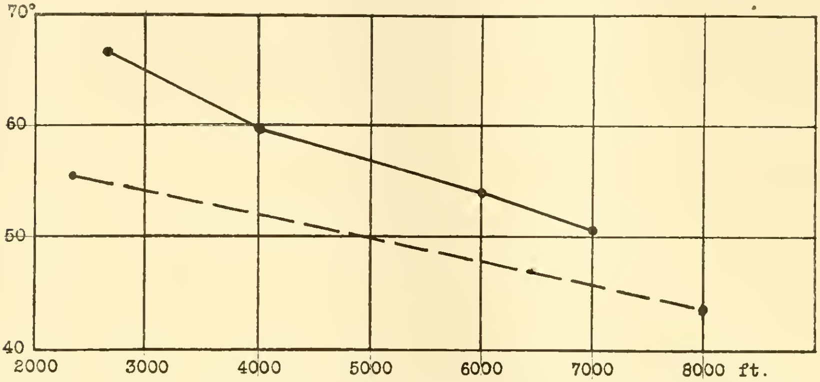

Fig. 1 Curves to show the fall of temperature with increase of altitude in the Santa Catalina mountains. Solid line, curve for ridge stations; broken line, curve for valley stations.

A vivid realisation of the importance of cold air drainage in relation to the vertical distribution of plants may be had by selecting a temperature on the ridge curve and then finding the elevation at which the same temperature occurs on the cañon curve. For example the mean minimum on the ridge at 7000 feet is 50.6°; by following in the abscissal direction to the cañon curve we find the same temperature at an elevation of 4650 feet. In other words the minimum temperature conditions of a ridge at 7000 feet will not be found in a cañon until we have descended to 4650 feet. A difference of topographic site at the same altitude is, then, the equivalent of 2350 feet (716 m.) of difference in altitude between localities of the same topographic situation. Comparing the 6000 feet station with its corresponding cañon temperature we have a difference of 3000 feet, but this is due to the increasing divergence of the gradients with descending altitude, which—as already stated—is probably not normal.

The influence of cold air drainage might be expected to affect both the upward limitation of lowland species and the downward occurrence of montane species. As a matter of fact the downward limitation of the forest and chaparral vegetation of the desert mountain ranges is due to the operation of the factors of soil and atmospheric aridity, and not to the chimenal factors. The limitation of the upward distribution of desert species appears to be attributable to chimenal factors, as the writer has shown for *Carnegiea gigantea.*[3] The writer has observed that a number of the most conspicuous desert species range to much higher altitudes on ridges and the higher slopes of cañons than they do in the bottoms and lower slopes of cañons. Samples secured by the writer indicate that there is no essential difference between the soil moisture of ridges and the bottoms of cañons during the driest portions of the year. Neither is there any evidence that desert species would fail to survive in the cañon bottoms if they were somewhat higher in soil moisture content. An explanation of the absence of the desert species from cañon bottoms and their occurrence at higher elevations on ridges must be sought in some operation of the chimenal factors rather than in the factors of soil and atmospheric moisture.

An analysis of the operation of the chimenal factors will be sure to discover that cold air drainage plays an important rôle in determining not only the lowness of the minimum, but also the still more important features of the duration of low temperature conditions.

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[3] Shreve, Forrest, The influence of low temperatures on the distribution of the giant cactus. The Plant World, 14: 136–146, 1911.

BOOKS AND CURRENT LITERATURE

A Desert Rubber Plant. Lloyd has published a monograph[1] dealing with the history, environment, morphology, reproduction, anatomy, histology, and cultivation of the Mexican rubber plant Guayule (*Parthenium argentatum* Gray).

This plant, discovered by J. M. Bigelow, M.D., in 1852, was described by Gray, who gives the first intimation of its economical value in the Synoptical Flora, 1886, in the statement that it produces a gum or resin. Its primitive use by the natives is reported, the rubber being extracted by mastication and used as a ball in the Indian games. Rubber from this source, extracted by a mechanical process devised by Mr. W. M. A Lawrence, was placed on the market in 1904. In 1909, according to Mr. Henry C. Pearson, the outlay of American capital in Mexico in connection with this rubber industry amounted to $30,000,000.

The total area over which Guayule is scattered is about 29,000 square miles, lying mostly in the 130,000 square miles which constitute the Chihuahuan Desert. The total original supply will be exhausted at the present rate of consumption, in from four to six years. Data on the environment are very meagre. The rainfall in 1907 is estimated at about seven inches; that in 1908 somewhat over ten inches. During 1907 the plants were in a practically dormant condition while good growth was recorded in June, 1908. The temperature (1908) ranged from 22.8° for January to 100° for May and June. No measurements of soil moisture are available. This factor controls the periods of growth of the Guayule plant, growth being slight in periods of subnormal rainfall. Guayule may be expected to flower in any month of the year if moisture conditions are favorable. The relative humidity of the region is comparatively high, and this is believed to account for the greater total growth than in the Arizona Desert. The rubber plant occurs normally only on the coarser soils of the ridges and is seldom found on the finer soils of the lowlands. Lloyd suggests that this is probably due to lack of aëration in the finer soil. In the opinion of the reviewer, the

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[1] Lloyd, Francis Ernest, Guayule: A Rubber Plant of the Chihuahuan Desert Carn. Inst. Wash., Publ. 139, pp. viii + 213, pls. 46. 1911.

Guayule with its deep root system would not find soil moisture conditions favorable in a heavy soil, when the amount of rainfall is only 7 to 10 inches, but would thrive on the gravel. Moreover it is doubtful if lack of aëration is a factor in arid soils, and until the soil moisture conditions are known, especially for the deeper layers of the soil, it seems unsafe to ascribe soil preference to lack of aëration. By the application of the quadrat method first described by Clements (Clements' name is, however, not found in the bibliography), Lloyd has given us two typical quadrats which should be of great value as permanent records of the vegetation of this great area. In this section of the work there are also given some interesting conclusions bearing on primary succession. The conclusion is reached that *Parthenium* cannot compete successfully with *Agave lecheguilla*, which therefore becomes the most objectionable of the native plants in so far as the natural crop of *Parthenium* is concerned. The principal enemies of the Guayule are rust, dodder and grazing animals. A bark beetle seriously damages the crop after harvest. The Guayule plant varies greatly in size. Usually a plant weighs from 500 to 600 grams and is from 40 to 50 cm. high. The greater number of the leaves which are developed during the period of sufficient moisture supply fall off during the dry period, only the clustered leaves at the end of the branches remaining until the following year. Leaf fall is therefore the direct effect of drought.

The greater part of the monograph is given to the histology of the plant. This is treated in considerable detail. The effect of irrigation on the anatomy of the plant is discussed in many places throughout the publication. It is found that starch remains in the endodermis much longer in irrigated than in unirrigated plants, also that more wood is developed in irrigated than in unirrigated plants. The medullary rays are narrower and there is less cortex. In other words the elements having to do with the conduction of water are much better developed in irrigated plants which supposedly have the greater amount of transpiration. The annular structure so distinctly seen by the eye, is not a true annular structure, nor is the true annular structure to be correlated with years of growth, since it represents only periods of growth which may or may not occur each year. On this account it is extremely difficult to estimate the age of plants and this difficulty is even greater with irrigated than with unirrigated plants. The resin canals are grouped in six primary and one secondary system and are of especial interest in connection with the formation of rubber in this plant. Rubber is not formed as a latex as in the majority of rubber plants, but is laid down in the cells themselves. It occurs in the parenchyma cells of the stems and roots and is secreted most rapidly in the cells of the resin canals, first in the roots and later in the stems. It usually appears in the tissues sometime after the cessation of active growth. The amount of rubber produced varies from 3.3 per cent in irrigated to 9.7 per cent in unirrigated plants. While the cortex of irrigated plants contains 4 per cent, that of unirrigated plants contains 15 or 20 per cent. Although the percentage of rubber produced is less in irrigated plants it is estimated that when one considers the increased growth, as much rubber if not more is produced than under natural conditions. It is, however, much more difficult to extract the rubber from irrigated plants on account of the increased wood production.

Reproduction of Guayule is easily accomplished by seeds which are produced rather abundantly or by cuttings provided they contain some of the tissue from the root zone of the plant. Plants thus produced are rapid growing and usually flower in a short time as compared with seedlings. The crop is usually harvested by pulling, but the rapid reproduction of new plants by the old roots make it advisable to cut off the plants in such a way as to leave some of the larger roots in the ground. Under natural conditions it is estimated that a plant of two pounds weight can be produced from seed in not less than fifteen years, while from the roots of old plants a period of but nine years is required. A fifteen-year rotation is advised and it is suggested that other plants which may be considered as weeds should be removed to decrease competition. Harvest should take place in the summer, if the season is a normal one.

As pointed out by the author the time available for the field work upon which this study is based was limited and this is doubtless the principal cause of the lack of data on environment and cultivation of the Guayule plant. All the data available were used however and the work is valuable as a contribution to many different lines. Histology and anatomy are the most thoroughly treated and this constitutes the most valuable part of the publication. The work suffers somewhat from the lack of suitable chapter summaries, and a final summary would greatly have increased the usefulness of the publication.—H. L. Shantz.

NOTES AND COMMENT

A large part of the general reading public think of science either as a congeries of marvelous and important medical discoveries and electrical inventions or else as the accumulating of very abstruse and useless facts by men of great erudition and absent-mindedness. The daily and weekly press and the monthly magazines are largely responsible for this attitude, and they now cater to it in a manner which is sometimes amusing to the man of science, sometimes calculated to wear the tender fabric of his good nature to the point of rupture.

A recent editorial article in The Philadelphia Press on Davenport's Heredity in Relation to Eugenics is a piece of childish drivel, carrying no intimation of the value of Davenport's work, making no criticism of it, and merely singling out one of two of its statements in a lame effort to say something amusing about them. A newspaper worthy of public respect would use its editorial columns to stimulate its readers to think, and not to provoke them to smile at a subject in which it might well wish to interest them. A recent issue of as dignified a weekly as The Nation gives two of the three columns devoted to science to a review of J. H. Robinson's Principles and Practice of Poultry Keeping. There is no gainsaying the possibility of putting much scientific method into poultry culture and of extracting many scientific facts from it. Can it be, though that The Nation beholds the scientific activities of the world at such a low ebb that it must go this far afield to secure matter for review? The Nation has, perhaps, a larger *clientèle* of thinking readers than any other American publication, but they are chiefly people to whom the best fruits of scientific work and thought are not well known. The few scientific books which it has space to review should, for this very reason, be extremely well chosen. Even Harper's Magazine, which presents so many excellent articles of scientific character, assumes that the weight of the name and professional connections of a writer will outbalance bootless sentimentality and serious misstatement of fact. In the March issue Dr. Edward A. Ayers, writing on The Seventh Sense in Man and Animals, says: "No living product of the vegetable kingdom finds use for equilibrial aids, for they are one with Mother Earth, and leave all questions of gravity, motion and balancing to her. Nor in the animal kingdom do home bodies like the oyster, anchored to one spot for life, find need of such aids. Nature bestows no luxuries, no organs that cannot be serviceably employed." The statement in the last sentence of this quotation is not only untrue, but it has been known to be untrue for over forty years.

We have a right to expect better things than these from the non-scientific press. We cannot carp at the daily papers for extracting humor from every available source of that valuable commodity, but they must not do so at the risk of discrediting a new and important scientific activity. We cannot expect The Nation to notice only the heavily technical outputtings of science, but we can and do expect it to give as much care to its science as it does to its drama, music and art. Neither do we exact technicality of the popular monthlies, but we do exact accuracy of them, both in facts and principles, even if it compels them to do what scientific journals so frequently do in submitting proffered manuscripts to competent judges outside the editorial office before accepting them.

The Fifth Annual Convention of Pennsylvania Foresters was in session at Harrisburg during the first week of March, numbering among its speakers Prof. Filibert Roth of the University of Michigan and Mr. F. A. Gaylord of the New York Conservation Commission. The convention again serves to bring the Pennsylvania forest service to public notice, and to remind us that it is the oldest and in many respects the best organized of the state forest departments. As long ago as 1893 a forestry commission was appointed in Pennsylvania, with Dr. J. T. Rothrock as chief. The work of the commission was organized as a division of the state department of agriculture in 1895, and in 1901 was constituted a department of forestry, with Mr. Robert S. Conklin as commissioner. An area of 972,000 acres has been set aside in state forest reservations, lying chiefly in the central and north central part of the state. They comprise some valuable stands of hemlock and hardwoods, but are mostly cut-over mountain lands, presenting to the forester a radically different set of problems from those involved in the management of the large western national forests. Over twenty men have been trained in the state forest academy and placed in charge of the scattered reserves. Three nurseries are maintained, and much has been done toward mapping and studying the reservations and providing them with roads, telephone lines and fire breaks.

THE RELATION OF EVAPORATION TO THE WATER CONTENT OF THE SOIL AT THE TIME OF WILTING

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It is well known that after a rooted plant has wilted and died as a result of drought, the soil still contains an appreciable quantity of water. This so-called "non-available" water content is known to vary with different soils and has been thought to vary also with different species of plants, but has usually been treated as constant for a given soil and species.

The wilting of a plant, as the soil becomes dryer, does not mean that the plant has ceased to obtain water from the soil but simply that the foliage is not obtaining it fast enough to replace that lost through transpiration. As the soil dries the films around its component particles decrease in thickness and the attraction of the particles for water apparently increases. Consequently as the soil becomes dryer it is increasingly more difficult for the plant to obtain water, and the latter passes into the plant more and more slowly. This continues until the plant cannot obtain moisture fast enough to replace that lost through transpiration, after which it wilts and finally dies. If, when a plant is about to wilt owing to the dryness of the soil, the rate of water loss were to be greatly checked, the plant should continue to be turgid until the soil has become still dryer, in other words, the lower limit of "available" water in the soil should vary with different rates of water loss through transpiration. Since transpiration is due to the ability of the air to remove water from the leaves, the soil moisture content at which wilting occurs should depend on the evaporating power of the air.

The effect of stomatal closure at the time of wilting, in reducing the transpiration rate, should not affect this conclusion.

Lloyd[1] has found that certain stomata, at least, do not close before wilting occurs, and points out that this closure is to be regarded as a wilting of the guard cells along with the other cells of the leaf. Even with all stomata closed, the rate of transpiration must vary with the evaporating power of the air. At any rate, the wilting of leaves, and the accompanying closure of their stomata is to be considered as a critical or end point of a drying process which has been going on for some time previously. Livingston and Brown[2] and Lloyd[3] have found that, under arid conditions, as the evaporating power of the air increases, the percentage moisture content of plant foliage markedly decreases; and that, apparently as a result of this, there is a corresponding fall in the rate of transpiration as compared with that of evaporation. This diminution of the percentage water content of leaves which has been termed incipient drying, is more pronounced under a high rate of evaporation than under a lower one. Renner,[4] in his thoroughly critical studies on the physics of water movement in plants concludes that there is always a saturation-deficit (''Sättingungsdefizit'') in transpiring leaves. The magnitude of this deficit should depend upon the transpiration rate and upon the rate of water intake by the roots; this deficit is identical with the incipient drying of Livingston and Brown. It appears that if the process of incipient drying be continued to a certain point, wilting occurs. This is quite in harmony with the view above stated, that the soil moisture content at the time of wilting should vary with the evaporating power of the air.

This conclusion does not imply, however, that the percentage of ''non-available'' soil water should vary with the rate of evapo-

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[1] Lloyd, F. E., The physiology of stomata. Publication 82 of the Carnegie Institution of Washington. 1908.

[2] Livingston, B. E., and Brown, W. H., Relation of the daily march of transpiration to variations in the water content of foliage leaves. Bot. Gaz. **53**: 311–330. 1912.

[3] Lloyd, F. E., The relation of transpiration to stomatal movements and to the water content of the leaves in *Fouquieria splendens*. Plant World **15**: 1–14. 1912.

[4] Renner, O., Experimentelle Beiträge zur Kenntnis der Wasserbewegung. Flora **103**: 171–247. 1911.

ration if the plants considered have been grown under different evaporation conditions, and were exposed, at the time of wilting, to the same rate of evaporation. Plants of *Martynia* and *Physalis*, grown under a low rate of evaporation, indoors at Tucson, Arizona, wilted immediately when exposed to the high evaporating power of the air outside; although both of these species grow spontaneously during the dryest part of the year, in places which are irrigated. This shows that the conditions under which a plant is grown are very important in determining those under which wilting occurs.

The experiments here reported were carried out at the Desert Laboratory of the Carnegie Institution of Washington, at Tucson during the summer of 1910. They deal with the relation existing between the evaporating power of the air and the percent of water in the soil at the time of wilting, for similar plants grown under similar conditions. This investigation was undertaken at the suggestion of Professor B. E. Livingston, to whom the writer is greatly indebted for valuable assistance during the progress of the work.

The evaporating power of the air at Tucson changes very greatly during the day, so that plants wilting at different hours must do so under very different rates of evaporation; but to secure still greater variations four situations were selected in which the evaporation conditions were quite distinct. These were: first in the open, exposed to the direct rays of the sun; second, under a lath shelter; third, in a room within a thick-walled adobe house; fourth, in a glass chamber in the same room, the air in this chamber being kept nearly saturated with moisture. The walls and roof of the shelter were built of laths placed parallel to each other, with openings equal to the width of a lath, about 3 cm. Under this shelter there were less sunlight and wind than in the open and consequently a lower evaporation rate. In the house the evaporation rate was still lower, owing largely to the still further exclusion of direct sunlight and wind. The shade temperature in the open and in the room were, however, practically the same. The evaporation rate was, naturally, very low in the nearly saturated atmosphere in the glass chamber. All of the plants used, except those of *Vicia faba*, were grown in the open until the beginning of the experiment.

The plants were grown either in ordinary five-inch flower pots or in zinc cans. Either method is open to objections. The flower pots, being porous allow water to evaporate from their sides, so that the soil near the outside may become dryer than that nearer the center. This objection was largely obviated by using the plants while they were small, when the roots were still chiefly in the interior of the soil mass; and by taking the soil sample from top to bottom, 2 cm. from the center of the pot. A cork-borer was used for this purpose, the upper 2.5 cm. of the core being discarded. The use of the zinc cans had the disadvantage that the temperature of the soil varied with the intensity of the sunlight, while the temperature in the pots, wherein the soil was cooled by evaporation, was comparatively free from this influence. For this reason the pots were used almost exclusively, and were employed in all cases except where cans are mentioned.

Each soil sample, as soon as taken, was put into a weighed bottle; weighed, dried for three days at 101° C., reweighed and the non-available water content calculated on the basis of the dry weight of the soil.

The evaporation rate was taken every hour by means of a porous cup atmometer, and the results were afterwards reduced to the standard which has been employed by Livingston.[5] The evaporation rate given with each experiment is for the hour immediately preceding wilting.

The soil used for growing the plants was a mixture of equal parts by dry volume, of clay-loam and sand. Both soil components had been passed through a 3 mm. sieve. The water holding capacity of the mixture was 31.4 per cent of the weight

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[5] Livingston, B. E., The relation of desert plants to soil moisture and to evaporation. Publication 50 of the Carnegie Institution of Washington. 1906.

Idem, A simple atmometer. Science, N. S. **28**: 319–20. 1908.

Idem, A rain-correcting atmometer for ecological instrumentation. Plant World **13**: 79–82. 1910.

Idem, Paper atmometers for studies in evaporation and plant transpiration. Plant World **14**: 281–9. 1911.

of the dry soil. A rough mechanical analysis of each soil is given in the following table.

TABLE 1

Analysis of clay-loam and sand

DIAMETER OF PARTICLES	CLAY-LOAM		SAND	
	Per cent by weight	Per cent by volume	Per cent by weight	Per cent by volume
mm.				
0.92–3.0	7.2	8	17.2	16.3
0.47–0.92	9.5	12	33.5	33.5
0.28–0.47	5.9	7	19.7	20.6
0.20–0.28	5.6	7	14.3	14.4
0.15–0.20	5.5	6	8.0	7.4
Less than 0.15 mm.	66.2	60	8.4	7.9

The experiments will now be described, each of the four species used being separately considered.

Martynia louisiana Mill. This species grows spontaneously, and in large numbers, near the Desert Laboratory during the moist mid-summer. It also occurs earlier, while the dry season is at its height, in irrigated places. This plant is therefore well suited to stand the high evaporation rate of southern Arizona. Similar plants of this species, which had been grown side by side in the open, were placed under the various conditions previously described and allowed to wilt. The percent of soil-moisture at the time of wilting, for each case, is given in table 2.

An examination of table 2 shows that there were considerable variations in the soil moisture content at wilting, even when this occurred under the same rate of evaporation. This was probably due in part to differences in the individual plants, and in part to the crude methods here resorted to. Considerable difficulty was experienced in deciding when one plant had reached the same stage of wilting as another. This was particularly true of *Martynia* and of *Physalis*, (the next plant to be considered) and may have introduced considerable errors. Another cause for error lies in unequal packing of the soil in the several pots. Despite these irregularities it seems clear, however, that there is, in general, a very close relationship between the soil water content at the time of wilting and the evaporation rate for the preceding hour. The highest soil moisture content (experiment 1) occurred in the case of a plant wilting in the open, with the highest evaporating power of the air; and the lowest percentage of soil moisture (experiment 16) was obtained in case of a plant wilting in the moist chamber. It is to be noted especially that an evaporation rate of somewhat over 7 cc. per hour invoked wilting with two or three times as much water still in the soil as was present when wilting was brought about under an evaporation rate of less than 1 cc. per hour.

TABLE 2

Percentage of soil moisture, at the time of wilting of similar plants of Martynia under different evaporation conditions

NUMBER OF EXPERIMENT	HOURLY EVAPORATION	SOIL MOISTURE AT WILTING	POSITION OF PLANT
	cc.	*per cent*	
1	7.5	17.5	Open
2	7.2	15.4	Open
3	7.2	12.0	Open
4	7.2	11.9	Open
5	6.1	11.7	Lath shelter
6	4.2	15.4	Open
7	4.2	11.3	Open
8	4.1	10.8	Lath shelter
9	3.2	10.5	Lath shelter
10	2.8	10.6	Room in house
11	2.8	6.8	Room in house
12	2.8	5.7	Room in house
13	1.7	4.3	Room in house
14	1.6	6.6	Room in house
15	1.3	6.7	Room in house
16	0.9	5.2	Moist chamber
17	0.5	5.4	Moist chamber
18	0.3	5.9	Moist chamber

Another kind of experiment was carried out. Three plants which had wilted under a high rate of evaporation were transferred to a position with a lower rate. Here they revived quickly without addition of water to the soil. They were then allowed to wilt in the new situation, which they did with considerably less water in the soil then in the first case. The results are given in table 3. These results bring out, perhaps in a still more convincing manner, the same generalization as that indicated above.

TABLE 3

Percentage of water left in the soil by the same plants of Martynia wilting under different rates of evaporation

NUMBER OF EXPERIMENT	HOURLY EVAPORATION	SOIL MOISTURE AT WILTING
	cc.	*per cent*
1	4.2 0.3	11.3 5.9
2	7.5 1.6	17.5 6.6
3	3.2 0.9	10.5 5.2

Physalis angulata var. *linkiana* Gray. This plant grows spontaneously near the Desert Laboratory under the same conditions as does *Martynia*, and it also is well suited to stand high evaporation rates. Similar plants of this species, which had been grown together in the open, were placed under the various conditions previously described and allowed to wilt. The percentage of water left in the soil in each case is given in table 4. The results are quite similar to those given for *Martynia*.

TABLE 4

Percentage of soil moisture at the time of wilting of similar plants of Physalis exposed to different evaporation conditions

NUMBER OF EXPERIMENT	HOURLY EVAPORATION	SOIL MOISTURE AT WILTING	POSITION OF PLANT
	cc.	*per cent*	
1	7.5	19.9	Open
2	7.5	12.7	Lath shelter
3	6.1	10.9	Lath shelter
4	4.0	9.3	Open
5	3.5	8.6	Room in house
6	3.2	6.9	Room in house
7	1.3	5.7	Room in house
8	1.0	7.8	Moist chamber
9	0.3	6.7	Moist chamber

In two cases plants which had wilted in the open, under a high rate of evaporation, were transferred to the house where the rate was much lower. Here they revived quickly without any addition of water, and wilted again in the new situation; but, like *Martynia*, with a considerably lower soil moisture content than was present in the first case. These results are given in table 5.

TABLE 5

Percentage of water left in the soil by the same plants of Physalis wilting under different rates of evaporation

NUMBER OF EXPERIMENT	HOURLY EVAPORATION	SOIL MOISTURE AT WILTING
	cc.	*per cent*
1	6.1	10.9
	1.0	7.8
2	7.5	12.7
	0.3	6.7

Tropaeolum majus Linn. This plant makes a good growth in the region of Tucson if started early in the spring, before the rate of evaporation becomes excessive. For these experiments seeds were planted in the early summer, which is the dryest season of the year, and the seedlings appeared to grow normally until they had developed eight or ten leaves. After this, growth was very slow and the plants did not appear healthy. The apparently unhealthy condition of the plants was probably due to their inability to obtain water from the soil fast enough to replace that lost through transpiration and at the same time to maintain the usual rate of growth. Livingston[6] has shown experimentally that with a high evaporating power of the air, a number of plant forms undergo a cessation of growth after the formation of only a few leaves, even though the soil in which they are rooted be maintained at or near what would be the optimum moisture content under less strenuous conditions of evaporation. With a lowering of the evaporation rate, and without any alteration in the soil condition, many of these same plants resumed their growth.

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[6] Livingston, B. E., Operation of the porous cup atmometer. Plant World, **13**: 111–18. 1910.

The experiments with *Tropaeolum* were performed when the plants had six or seven leaves and still appeared to be in healthy condition. The results are given in table 6.

TABLE 6

Percentage of soil moisture at the time of wilting of similar plants of Tropaeolum exposed to different evaporation conditions

NUMBER OF EXPERIMENT	HOURLY EVAPORATION	SOIL MOISTURE AT WILTING	POSITION OF PLANT
	cc.	*per cent*	
1	7.4	17.8	Open
2	7.4	17.5	Open
3	5.5	18.7	Lath shelter
4	5.5	9.6	Lath shelter
5	4.8	14.4	Lath shelter
6	2.8	7.0	Room in house
7	1.4	5.3	Room in house
8	1.0	7.4	Room in house

The results given in table 6 agree in a general way with those given for *Martynia* and *Physalis*, but the individual variations shown by *Tropaeolum* are much greater than in the other two cases. This may well be due to the adverse conditions under which the plants were growing.

The results obtained from two cases in which the same plant was successively exposed to two different rates of evaporation and allowed to wilt are given in table 7. As in the cases of *Martynia* and *Physalis*, the plants revived without the addition of water, when they were transferred from the position with high rate of evaporation to that with a lower one. These data point to the same conclusion as do those previously given.

TABLE 7

Percentage of water left in the soil by the same plants of Tropaeolum wilting under different rates of evaporation

NUMBER OF EXPERIMENT	RATE OF EVAPORATION PER HOUR	SOIL MOISTURE CONTENT AT WILTING
	cc.	*per cent*
1	5.5	18.7
	1.0	7.8
2	2.8	7.0
	1.4	5.3

Vicia faba Linn. Seedlings of this species, grown under the lath shelter during the summer, had a normal appearance but they were not able to bear the high evaporation rate of the open; it was found impossible to grow them under full sunshine. For these experiments the plants were grown under the lath shelter, behaving normally until they had attained a height of from 15 to 20 cm. After this, however, they wilted regularly during the middle of the day. As will be seen from table 8, this was the case even when the soil was saturated beyond its water holding capacity (31.4 per cent). After reaching this stage growth practically ceased and the plants soon died.

Table 8 gives the water content of the soil for plants about 15 cm. high, wilting under the lath shelter and in the house. All of the plants under the shelter wilted at approximately the same time, but with very different amounts of water in the soil. This suggests that, in this case, the time of wilting may have depended more on the rate of evaporation than on the moisture content of the soil, and that the death of the plants a few days later may have been due to excessive transpiration coupled with inadequate power of water conduction.

TABLE 8

Percentage of soil moisture at the time of wilting of similar plants of Vicia exposed to two different evaporation conditions

NUMBER OF EXPERIMENT	HOURLY EVAPORATION	SOIL MOISTURE AT WILTING	POSITION OF PLANT
	cc.	*per cent*	
1	4.2	36.4	Lath shelter
2	4.2	31.8	Lath shelter
3	4.2	24.7	Lath shelter
4	4.2	24.3	Lath shelter
5	4.2	23.3	Lath shelter
6	4.2	22.6	Lath shelter
7	4.2	21.2	Lath shelter
8	4.2	20.4	Lath shelter
9	4.2	19.3	Lath shelter
10	4.2	17.8	Lath shelter
11	1.1	8.3	Room in house
12	1.1	8.0	Room in house
13	1.1	7.9	Room in house
14	1.1	7.5	Room in house

The data given in table 8 show that in these experiments *Vicia faba*, like the other three species, wilted with a greater percentage of water in the soil when the rate of evaporation was high than when it was lower.

The results of the above experiments, with *Martynia*, *Physalis*, *Tropaeolum* and *Vicia*, clearly show that determinations of the percentage of soil moisture at the time of wilting,—at least for these plants and for the soil here used,—are of no value unless the evaporating power of the air, at least for the period just preceding the time of wilting, is taken into account, and it is quite probable that this is also true for all ordinary plants and soils.

Another interesting and apparently fundamentally important point is brought out by a comparison of the data of tables 2, 4, 6, and 8. The moisture content of the soil at the time of wilting is seen to vary among the different plants within but comparatively narrow limits for any given evaporating power of the air during the hour preceding wilting. Thus, with an evaporation rate from the standard atmometer of from 7.2 to 7.5 cc. per hour, the percentage of residual water content of the soil here used was 11.9 to 17.5 for *Martynia*, 12.7 to 19.9 for *Physalis*, and 17.5 to 17.8 for *Tropaeolum*. With the evaporration rate between 0.9 and 1.6 cc. per hour these limits are 5.2 to 6.6 for *Martynia*, 5.7 to 7.8 for *Physalis*, 5.3 to 7.4 for *Tropaeolum* and 7.5 to 8.3 for *Vicia*. The most marked exception to this generalization is shown by *Vicia*. (table 8, experiments 1 to 10) with an evaporation rate of 4.2 cc., in which case wilting occurred with a soil water content of from 17.8 to 36.4 per cent. Under high evaporation rates *Vicia faba* is able to maintain its form for but a short time, as has already been noted, and we may suppose that these extraordinarily high residual moisture contents are due to the fact that the limits for the general life activities of this plant have been surpassed and that the physical system of its body is somehow in process of breaking down. Some of the results obtained with *Tropaeolum* suggest a similar interpretation. But it appears to be fairly clear from the general nature of the data here given that, within a wide range of intensities of the evaporating power of the air, we may expect a given evaporation rate to produce wilting in different plants growing in the same soil, with about the same soil moisture content. This is not in agreement with what is usually stated, but has been convincingly substantiated by the work of Briggs and Shantz,[7] who have arrived at the same conclusion as that just given from an extensive series of experiments with many plant forms, well distributed in the natural system.

That high soil temperature may affect the percentage of residual soil water at the time of wilting, is shown by the following observations. When plants grown in zinc cans were allowed to wilt in the open, where they were exposed to the direct rays of the sun, the temperature of the soil was always higher than in flower pots similarly placed. Under these conditions the percentage of residual water was greater for the plants in cans than for those in pots. When, however, the plants wilted in the room or in the moist chamber, both the temperature of the soil and the percentage of residual moisture were practically the same in the two cases. From this it appears that excessive soil temperatures, like high evaporation rates, increase the amount of soil moisture which is present at the time of wilting.

If the soil in which the plants were growing was very moist when they were transferred from the open to the room or to the moist chamber, it took several days for the soil to become dry enough to produce wilting. In such cases the plants always wilted with a higher percentage of water in the soil than in the cases where the soil was sufficiently dry at the time of transfer so that wilting occurred within twenty four hours. This shows how capable these plants are of acclimatization, and emphasizes the importance of the internal conditions of the plant in determining the soil moisture content at the time of wilting.

Briggs and Shantz (*loc. cit.*), in their thorough-going treatment of certain phases of wilting in relation to soil moisture, found that rather marked differences in humidity and sunlight

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[7] Briggs, L. J., and Shantz, H. L., The wilting coefficient for different plants and its indirect determination. Bulletin 230, Bureau of Plant Industry, U. S. Dept. of Agric. 1912.

had no considerable effect upon the soil moisture content at the time of wilting, *providing that the wilting occurred under the same general environmental complex under which the plants had been grown.* This proposition clearly supports the suggestion just made, that, in order to bring out the remarkable relation between the evaporating power of the air and the soil wilting point, it is quite essential that the internal physical system of the plant be not allowed much time for alteration. If the internal conditions be allowed to change (as by a process of acclimatization) or if they be differently established from the start (as by growing plants under various external conditions), then, although the plants may still seem alike to the eye, yet they differ markedly in their physiological nature and are really different kinds of organisms. By this consideration it is seen that what appears to be a fundamental discrepancy between the conclusions of Briggs and Shantz and those here expressed is probably not a serious one, if it is a discrepancy at all. The problem treated in the present paper is quite a different one from that attacked by the authors just mentioned and the two conclusions may well stand together.

With the usual lack of uniform methods in physiological experimentation in the hands of different workers, it is unfortunate that no criterion for the quantitative comparison of the data here given with those of Briggs and Shantz can be established. The only physical analysis of the soil here used which was possible at the Desert Laboratory in the summer of 1910 is far too crude to be of value in comparing the soil mixture of these tests with the soils of the Washington authors. Furthermore, their water-holding capacities were determined with a soil column one centimeter high, while the determination mentioned earlier in this paper was made with a 10 cm. column. Briggs and Shantz have omitted any quantitative description of the aerial conditions of their experiments, so that the atmometer data of the present paper are of no avail for a common criterion. This is greatly to be regretted, and it is to be hoped that workers in physiology and ecology will eventually realize the importance of atmometric records in specifically defining the aerial conditions under which experiments are performed.

It is certain that the problem of wilting here dealt with will require a great deal of very carefully planned study before any satisfactory general conclusion may be reached. For the present, it seems advisable to regard the definite conclusions of Briggs and Shantz as probably applicable only to a special complex of aerial conditions.

SUMMARY

The percentage of soil moisture at the time of wilting for similar plants of *Martynia louisiana, Physalis angulata* var. *linkiana, Tropaeolum majus,* and *Vicia faba,* grown under the same conditions and in the same soil, has been found to vary with the rate of evaporation at the time of wilting, providing however that, in the case of altered conditions, the plant is not allowed time enough under the new evaporation rate to become physiologically altered.

This residual moisture content of the soil at the time of wilting varies according to the atmospheric conditions under which the plant has been grown and appears to be increased by excessive soil temperatures.

THE KELLERMAN PLANT PRESS

HENRY S. CONARD

Grinnell College, Grinnell, Iowa

Some years ago the late Professor Kellerman published in Science a note describing a quick method of drying plants for herbarium collections. He had used it with entire success in the reeking tropical climate of Guatemala. In the summer of 1910 the present writer arranged a similar press at the Biological Laboratory of the Brooklyn Institute of Arts and Sciences at Cold Spring Harbor, Long Island. It was so satisfactory that several persons who saw it have adopted the scheme. During the following autumn Professor Collins, then of Brown University, described the process before the New England Botanical Club in a paper later published in Rhodora (vol. xii, p. 221–224). We have since used it in our college laboratories, to the delight of both students and instructors. While, therefore, there is nothing new in our device, we think every field botanist should be acquainted with it, and every teacher who dries specimens or requires students to do so, should know and use it.

In brief, the Kellerman press consists of two board sides 11 by 17 inches, in which corrugated pasteboard is used in place of blotters. The corrugations run crosswise of the sheets, being backed by plain pasteboard on one side. These boards are laid between the plants exactly as blotters were formerly used. When the press is full, say 18 inches thick, it is tied up tightly with a cord around each end. The press is then hung by the cords on two hooks, so that the corrugations of the driers stand vertically. A canvas skirt or tube is tied tightly round the press with a drawing string, and a kersoene lamp is placed under the skirt. The hot air from the lamp rises in the skirt, passes through the corrugations on each side of each plant, warming and drying them. Ferns and tree leaves of Long Island dry readily in twenty-four hours. Specimens collected today may be mounted, labeled, and stored in the permanent herbarium tomorrow. Saltworts and prickly pears require two to four days to dry. They do not grow in the press as *Talinum* and *Sedum* used to do in the blotters.

For those who wish more detailed specifications, we may outline our own method of operating the press. In the field I usually carry on my back a light slat press with three projecting strips on each side. A stout cord is wrapped around the ends of these strips to hold the press together. Two half-inch ropes tied into the ends of one side of the press enable me to hang it on my shoulders like a knapsack. A big cord properly run through the slats of the other side is used for attaching general baggage—manual, maps, accession list, lunch, blankets, etc. Both hands are thus left free for any use that may come to them. One can easily carry in addition a vasculum on one shoulder and a camera on the other. Before starting out we fill the press with fifty to two hundred sheets of the thinnest and cheapest unprinted newspaper, cut to 11 by 17 inches. Printed newspaper is just as good. On reaching the collecting grounds we gather plants in hand until they begin to show the first signs of wilting. Then we sit down in a spot sheltered from any breath of wind, lay the plants on our right, and the press on our lap with the baggage side up. The cord is loosed, the loaded side of the press laid off to the left, and the papers laid on top of it. Then we lay two sheets of paper on the press, cover with plants, lay on two more papers, then plants, then two papers, and so on until all the plants are put in. A stick, leaf, or stalk of grass laid with one end projecting from the press serves to mark the place where we leave off putting in plants at this sitting. The empty papers are replaced, and all made fast with the cord. Next time we begin at the projecting grass or leaf and proceed as before. This is repeated until the day's work is done, when we return to the laboratory.

Field work has to be conducted in Iowa on rather different lines from those followed in Long Island. Rarely is the air still enough on the prairies to use the field press. This makes the securing of good specimens much more difficult. For in nature every leaf and flower is perfectly spread out, and if clapped into the press quickly, all this natural grace of position is well preserved. But the prairie winds blow our papers about hopelessly, and dry our plants before we have time to seek a sheltered spot. So we must collect in vasculums, and spread our specimens on newspapers as best we can in the laboratory or tent. I had less difficulty collecting in the desert of New Mexico and in the misty forests of Washington State than on the Iowa prairie!

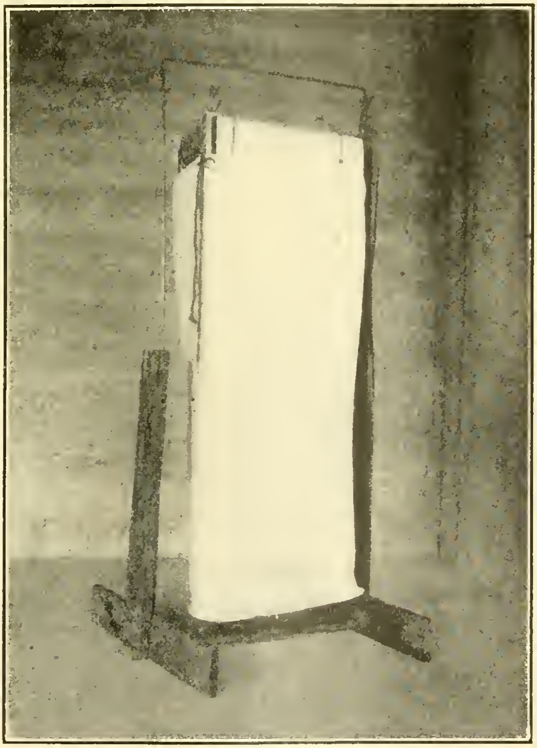

Fig. 1 The Kellerman Press on its rack.

My laboratory press consists of two light slat sides, inherited from the days of blotters. We wrap them in strong paper to keep the hot draft from being lost through the slats. We lay one of these sides on a table, on the left of it a pile of corrugated driers, and on the right the opened field press with any unused papers removed. Then it is simply a matter of piling up. I like to have an assistant do this! On the laboratory press is laid first a corrugated drier, then two sheets enclosing a plant from the field press, then a corrugated drier, and so on until the pile is sufficiently high. The press is tied with quarter-inch rope, as tightly as we can squeeze it. The rack on which we hang it at Cold Spring Harbor is made of a 12 foot long by $\frac{1}{2}$ in. iron rod, bent in a U-shape. The legs are 5 feet long and the horizontal part 2 feet. Two wires wound round the cross bar and bent to a hook 4 inches below it serve to hold the cord when the press is hung up. Thus the weight of the press keeps the cords constantly tight, and the sides follow the plants as they shrink in drying. The iron work is supported by two vertical wooden supports fastened to cross pieces which lie on the floor. This makes an easily portable apparatus. The skirt that is tied round the press is made from two four-foot lengths of thin fire- and waterproofed canvas 30 inches wide. Both selvage edges are sewed together, and both ends of the tube hemmed. In the upper end a drawing string of quarter-inch cord serves to tie the skirt around the press. In the lower end a wire is inserted to keep the skirt spread wide open at the bottom. These dimensions bring the bottom of the skirt about 4 or 5 inches from the floor, allowing ample ventilation for the lamp. We use any ordinary flat wick kerosene lamp, with an oil reservoir large enough to supply the flame for at least twelve hours. A 2-inch burner is desirable, but 1-inch will suffice.

In our home laboratory the press hangs near a column in the middle of a large laboratory room. We have a shallow galvanized iron pan under it, in case of accident. Though I never had any indication of danger, I would prefer to keep the outfit in a fireproof room. In early spring and late autumn we simply lay the press on edge on a steam radiator, obtaining the best of results without a trace of risk.

The satisfaction to the teacher of having today's collections ready for study at tomorrow's class will be easily imagined. One can require collections with an easy conscience when the student spends all of his time with the plant rather than with blotting pads. The collector finds about ten times the return for his time by this system that he could get with blotters. And in damp weather the two methods are not comparable! The specimens are of course better for having dried quickly. I have *Baptisia tinctoria* in good color but have not yet obtained *Monotropa uniflora* without blackening. Rarely does any trace of the corrugations appear on the plants, and never yet in my experience to their detriment.

BOOKS AND CURRENT LITERATURE

The Eusporangiate Ferns.[1] It is just twenty years since Professor Campbell first called attention to the Ophioglossaceae and Marattiaceae, which together make up the Stipulatae of Sachs, or Eusporangiatae of Goebel, as the most primitive of living Filicales. The present paper[1] gives us the consummation of the investigations initiated by the author two decades ago. It furnishes a worthy example of long-sustained interest and persistent effort in the solution of one problem. The outcome is the accumulation of a large series of facts concerning the structure and development of these ferns, which serve as a substantial foundation for his hypothesis concerning their relationship to each other and to other Filicales. Besides summarizing the earlier work of the author and that of other writers, the book gives the results of the detailed study of fourteen species of these two families, including examples of all the genera except the recently discovered *Arcangiopteris* and *Macroglossum*. Some of the subject matter and certain of the drawings have already appeared in the recent papers of the author.

The memoir is divided into three parts, dealing respectively with the Ophioglossaceae, the Marattiaceae and the origin and relationship of the Eusporangiatae. In Part I Campbell discusses, in one section, the germination of two species of *Ophioglossum;* the structure, including histology and the mycorrhiza of the prothallus of four species of *Ophioglossum*, one of *Botrychium* and one of *Helminthostachys;* finally, the development of the sexual organs is described, including the spermatogenesis of all three genera. In a second section or chapter, on the embryo, the origin of the primary organs of the sporophyte is described for two species of *Ophioglossum*, and one of *Botrychium*. The most striking feature of this development is the late appearance of the stem, in an embryo that for a long time consists solely of a root and a cotyledon with a continuous vascular bundle running through both. The most important discovery described in a third section, on the young sporophyte, is the character of the vascular system of the latter. This is made up

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[1] Campbell, Douglas Houghton: The Eusporangiatae; The Comparative Morphology of the Ophioglossaceae and Marattiaceae. Carn. Inst. Wash., Publ. 141, pp. 235, pls. 13, figs. 192. 1911.

entirely of leaf traces, fused with each other, and with those of the root and cotyledon, but without any trace of cauline elements, coming from the plerome of the stem apex. This fact strengthens the conclusion that the young plant is made up, primarily, of root and cotyledon only. In a fourth section of Part I it is shown that the same mode of origin of the vascular system is found at the apex of the mature stem. A true cambium is present in the stem of *Botrychium*, even when but five or six leaves have been developed. The fertile portion of the sporophyte Campbell regards as a structure *sui generis*, or sporangiophore, as was suggested by Bower, and does not admit that it can be the equivalent of one, or two, fused pinnae, as held by Goebel and by Chrysler. In studying the development of the leaf Campbell finds that the fertile and sterile portions arise by a dichotomy of the leaf rudiment. The vascular system of the spike arises from parts of two bundles, the remainders of which continue on to form parts of the vascular system of the sterile blade.

In Part II Campbell discusses, in the same detailed manner, the gametophyte, embryo and mature sporophyte of *Marattia*, *Danaea* and *Angiopteris*. He notes the occurrence in the green prothalli of these forms of a mycorrhiza, similar to that in the subterranean prothalli of the Ophioglossaceae. The sexual organs are found to be similar to those of the latter family, as is the spermatogenesis, which was studied in *Danaea* and *Kaulfussia*. In the development of the embryo the root arises secondarily, and it, as well as the stem and cotyledon, is derived from the epibasal half of the oospore, probably from the same octants as the cotyledon. The vascular system of the very young plant consists of fused leaf traces only. In a plant of *Danaea jenmani* with seven leaves, a commissural strand had appeared, which is derived directly from the plerome of the stem apex. This small commissural strand is developed, at this time or later, in all the Marattiaceae studied. In this study of the vascular system one could wish that every possible means had been taken to locate the elusive endodermis, because of its value as a definite boundary line. The peculiar groups of sporogenous cells arise, in contrast with those of the Ophioglossaceae, on little modified leaves. Campbell rejects the view that the latter have arisen by the fusion of the fertile and sterile portions of a leaf like that of *Ophioglossum*. He suggests that the sporophylls of the Marattiaceae may have arisen by the gradual sterilization, extension and flattening of part of the tissue of a sporangiophore, as sometimes occurs to a striking degree in *Helminthostachys*. In spite of the differences in the sporophylls there are many features in which the sporophyte of the Marattiaceae, especially that of *Kaulfussia*, resembles that of the Ophioglossaceae.

In Part III, the origin and relationship of the Eusporangiatae, Campbell points out that, in the absence of adequate evidence from fossils, we are dependent on comparative study of living forms in determining the phylogenetic position of the Eusporangiatae. Starting from the assumption, made for reasons given in his "Mosses and Ferns," that the sporophyte of the Eusporangiatae is descended fom that of a liverwort-like form, he chooses *Anthoceros* as the nearest living form to this ancestral liverwort. He then points out the essential similarity of the sexual reproductive organs of *Anthoceros* and the Eusporangiatae and compares the late fruiting, persistent sporogonium of the former with the tardily differentiated sporophyte of, *e.g.*, *Ophioglossum*. He is finally led to the suggestion that if the sporogonium of *Anthoceros* were to develop a root from its basal meristem, it would form thus a sort of "*Pro-Ophioglossum*" from which the known species of *Ophioglossum* might have descended. Through them could readily be derived the other Eusporangiatae and perhaps all the rest of the Filicales. The first leaf of this primitive *Ophioglossum* was probably fertile and the sterile leaf blade is believed to have sprung, like the root, from the prolific and versatile basal meristem. This well thought-out hypothesis is still far from entirely satisfactory. It does however escape at least a part of the force of the criticism recently directed by Scott against the antithetic theory of alternation, that "no one ever saw an intermediate stage between a sporogonium and a leafy stem." It is evident that Campbell needs to postulate the origin of but a single flattened outgrowth from the base of the sporogonium, a structure of the sort which has an actual counterpart in the apophysis of the moss *Splachnum*. The further evolution of the shoot to a "leafy stem" is, if we entertain the rather generally accepted view of the relationship of *Ophioglossum* to its allies, not a question of hypothesis but of fact.—D. S. Johnson.

The Prairies of Iowa.—Although the papers that have been written in explanation of the prairie are almost numberless, it is with unalloyed pleasure that we welcome Shimek's recent paper[1] on this subject, since it is one of the first to present exact data. For many years the author has been interested in the study of the tension line between

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[1] Shimek, B., The Prairies. Bull. Lab. Nat. Hist. State Univ. Iowa, 6: 169–240, pls. 14. 1911.

forests and prairies, affording still another reason for placing this contribution in the first rank. It is estimated that seven-eighths of the area of Iowa was occupied originally by prairie, this area embracing almost every type of topography and lithological substratum. After listing and discussing the characteristic plant species of the prairie, Shimek considers the relation of the vegetation to various factors, especially to evaporation, which is thought to be the chief determining factor. Careful experiments with evaporimeters, coupled with long observation, lead the author to believe that exposure to a high degree of evaporation is the chief cause of treelessness. Rainfall and drainage are not determining factors in Iowa, both frequently being equal on contiguous forested and treeless areas. Prairie fires as a cause are discussed at length and are very properly ruled out as factors of large importance. It seems to the reviewer that the author has proved his case better than anyone who has previously written on the subject, and that the much-vexed problem is nearing solution. The paper closes with an admirable bibliography. The plates are well selected and several of them show a striking difference between the vegetation of opposing slopes, which is clearly related to differences in evaporation.—HENRY C. COWLES.

UNINUCLEATE AECIA.—Students of the problems relating to the sexuality of fungi will be interested in a brief paper by Miss Moreau.[1] She finds an aecidial form parasitic on *Euphorbia silvatica*, which bears aecia with only one nucleus. The mycelial cells are also uninucleate, as are the mother cells, which give rise to the chains of aecia and the intercalary cells. Since she was unable to bring about the germination of these spores, we do not know whether they germinate as normal aecia or as in *Eudophyllum*. Should Miss Moreau's observations be substantiated, this will prove to be the first exception to the generally accepted law, that aecia are always binucleate—FREDERICK A. WOLF.

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[1] Moreau, Mme. Fernand, Sur l'existence d'une forme écidienne uninucléé Bull. Soc. Mycol. France, Tome **27**: 489–493 (1911). 1912.

NOTES AND COMMENT

A striking review of the development of botanical science since Nägeli, Pringsheim, De Bary, Tulasne, and Hofmeister opened the ways for studies in the physiology of plants, for studies of the fungi and of the algae of fresh waters and of the sea, and in morphology, and since Darwin published his Origin of Species, is given as a Rektoratsrede by Professor Ed. Fischer. The occasion was the seventy-sixth anniversary of the founding of the University of Bern. Fischer sums up his review (Ein Menschenalter botanischer Forschung, Akademischer Buchhandlung, Bern, 1911) by the assertion that the period in question, the span of a man's life, is characterized by two things—the emphasis of the physiological and biological point of view, and the domination of the doctrine of descent. Botanical science, no longer content with ascertaining what is and building hypotheses upon these facts, has learned to follow the course of their development and the conditions which affect if they do not control it. Culture, pure-culture, and experiment are now made to throw what light they can even upon questions of descent. And of late years we find botanists associating themselves with physicists and chemists, if they do not themselves become such, for deeper study of what is, rather than continuing their independent speculations about what was.—G. J. P.

Rapid progress is being made in the field of applied mycology, both by reason of the utilisation of the scientific work which has been done, and because of the stimulating effect which practical needs have exerted on the character of the work in scientific mycology. A striking evidence of this progress is afforded by the nearly simultaneous establishment of the Zeitschrift für Gärungsphysiologie, allgemeine, landwirtschaftliche und technische Mykologie, published by Gebrüder Borntraeger, and the Mycologisches Centralblatt, published by Gistav Fischer.

Blakeslee and Jarvis have prepared a handbook for the study and determination of New England trees in the winter condition (Bull. 69, Agricultural Experiment Station, Storrs, Conn.). One hundred and ten species are described, and illustrations are given to show their habit of branching and the appearance of their bark and twigs. The bulletin will doubtless be useful throughout the northeastern states.

THE BEHAVIOR OF THE NECTAR GLAND IN THE CACTI, WITH A NOTE ON THE DEVELOPMENT OF THE TRICHOMES AND AREOLAR CORK

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The occurrence of extra floral glands in the Cactaceae has long been known[1] and these structures have been used as taxonomic characters. Ganong, in 1894, indicated their occurrence in a variety of species of the genus *Opuntia*, and examined them from the morphological-physiological point of view, describing in detail their structure and mode of secretion in *Opuntia arborescens*. He pointed out, also, that, at the time of his publication, they were known in *Mamillaria*, *Rhipsalis* and *Cereus*. This list was extended in 1908[2] to include *Echinocactus*, of which several species were found to have nectar glands on the mamillae. Other genera might have been included but for the lack of suitable identifications.

The purpose of this paper, however, is to rediscuss the structure and the mode of secretion, as indicated by certain cytolytic changes, of the cactus extrafloral nectar gland, which according to Ganong, may be homologized with the thorn, a conclusion fully supported by the evidence. After describing their development, Ganong says of the histology of the gland: "die Zellen bleiben noch unverholzt und inhaltsreich, und eine Cuticula sondert sich ab, zwischen welcher und der Drüsenoberfläche der Honig ausgeschieden wird. Schliesslich zerreisst die Cuticula und der Honig steht als grosser

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[1] Pertinent references are given by Ganong, W. F., Beiträge zur Kenntnisse der Morphologie und Physiologie der Cacteen. Flora, Erganzungsbd, 1–40, 1894.

[2] Lloyd, F. E., Extra-floral nectaries in the cacti. Plant World, 11: 138–140, June 1908. The senior author regrets that, at the time of writing this paper, he was in ignorance of Ganong's work on the nectar gland and neglected, therefore, to cite it.

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Tropfen auf der Drüse (*t. c.*, 10, 11). This description is accompanied by a figure (his fig. 5) of the tip of a "nectarial thorn" of *Opuntia arborescens*, represented as a solid object. Sections of the structures in question are not reproduced. In a discussion of the matter which the senior author had with Professor Ganong, the latter took the position indicated by the above quotation, upon which they fell into amicable disagreement, the senior author maintaining that, in contravention with the many known cases in which the secretion of oils, resins, and the like occurs between the outer cell wall of the epidermis and its cuticle, that of nectar in the Cactaceae is accompanied by a release of the whole epidermis. In the present paper is offered evidence which shows that each in part was right.

Echinocactus uncinatus[3] (figs. 1 to 5). Of the glands which we have examined, that of this species in particular, on account of its large size, presents great ease of examination. It is dome shaped, supported on a thick pedestal in which the vascular tissues supplying the glandular tissue proper spread out (fig. 1). Surrounding the gland are numerous trichomes which fill the sulcus of the mamilla with a dense felt. Many of them are lignified and it is probable that their numbers increase with the age of the mamilla. The body of the gland is composed of cells, which, at its base, are nearly isodiametric. Above the base they are elongated (fig. 3), and gradually become thicker-walled as the apex is approached. Here they are again isodiametric and have the thickest walls.

The epidermis as it ascends the base of the gland becomes markedly thicker, this being due to increase in the thickness of the outer wall, and this again especially to the marked increase in the thickness of the cuticle. This thickening, accompanied by cutinization, is extended also into the radial walls (fig. 3) throughout the greater extent of the tissue. Areas occur, usually at the tip of the gland, but elsewhere also, where this thickening of the radial walls does not occur (fig. 4). It is further important to notice that the cutinization may pass entirely down to the inner

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[3] No. 10, Cacti of Northern Zacatecas, collected by F. E. Lloyd and deposited in the National Herbarium.

wall of the epidermis especially, at the angles of the contiguous cells and that this may extend from said angles into the inner periclinal walls. There results from this condition a more or less complete network of irregularly cutinized strands (fig 5) marking the outlines of the inner periclinal walls of the epidermal cells. The non-cutinized cell walls are, so to speak, supported within this curious framework of cuticle, which, moreover, may be laid down throughout the whole of the cell wall, especially in those radial walls which lie longitudinally with respect to the axis of the gland as a whole. But, on the other hand, it is frequently discontinuous, so that a short portion of the radial wall, even at the angles of contiguous cells, remains uncutinized (figs. 3, 5). A brief study of our figures will serve to make these relations clear. It will be seen, also, that of the total thickness of the outer wall of the epidermis, the cutinized portion is far in excess of the cellulosic part.

The beginning of secretion is evidenced in the eruption of the *whole outer cell wall*, the radial, and sometimes even the inner walls being torn away, leaving their cutinized portions attached to the top of the gland (fig. 3). Preparations treated with alkanna bring out these facts unequivocally.

Meanwhile, there is a concomitant disintegration of the remaining cellulose walls and of the protoplasm, in which a small amount of oil appears as minute droplets (fig. 3). On the surface of a gland of which the whole apical area is freed from the capping epidermis there can eventually be found little or no trace of either the cellulose of the cell walls or of the protoplasm, more, however, toward the periphery of the exposed glandular area than toward the center. Some glandular material, strands of inner cuticle (fig. 5) and masses of calcium oxalate intermixed adhere, however, in an irregular, amorphous layer. As the gland ages, there is a further accumulation of this salt in the upper part. In the base of the gland, spheroids of calcium oxalate are in evidence, sometimes associated in the same cell with rhomboids. In fact, the whole appearance of the upper portion of the gland indicates that there has occurred an autolysis of the cellulose walls and of the protoplasts of the cells involved. That sugars occur is shown by a ready reaction, with Fehling's reagent, of the solution of a few droplets taken from the tips of active glands.

Mamillaria sp.[4] (figs. 9 to 11). This is a species with large mamillae, in which two glands occur in the furrow quite near the rosette of spines. The gland is of peculiar interest in this connection because, when the dissolution of the epidermis begins at the apex of the organ, the first evidence is seen in the separation of the *cuticle alone* from the cellulose wall (fig. 10). In shape the gland is disc-like, with a slightly concave upper surface, and is raised on a tapering base clothed with long trichomes (fig. 9). Histologically, it is similar to that of the *Opuntia* described beyond, except that the cuticle is heavier, and that, in harmony with its squat form, the glandular tissue, distinguished by thickened cell walls, is shallow (fig. 9, *g*), while the underlying, thin-walled non-glandular cells are only slightly elongated. In the epidermis there is neither inner cuticle for any thickening of the radial walls as in *Echinocactus*, and the cellulose constituent of the outer wall is relatively considerably thicker.

The first step in the approach of secretive activity is seen in the release of the cuticle covering of some thirty or forty epidermal cells at the extreme apex of the gland. With the material at hand, it is impossible to determine whether there is at this time an accumulation of nectar in the hiatus between the cuticle and the corresponding cells beneath. Observation on the fresh material in Mexico led the senior author to the belief that such is not the case, since it was frequently noticed that the tops of young glands showed the presence of air beneath the cuticle. The point is important, but cannot be settled except by more careful examination of the young glands in a fresh condition.

Very soon after the cuticle begins to be set free, the underlying cells disappear, the cellulose wall being digested (fig. 11), as also the protoplasm. One finds evidence for the digestion of the cell wall in the separation of the cell, not only from the cuticle, but from the middle lamella and from the underlying cells of the gland, and in the thinning and collapse of the cell wall itself. The rate

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[4] No. 40, Lloyd, Cacti of Northern Zacatecas. National Herbarium.

at which the disorganization of the cell contents takes place carries this forward somewhat in advance of the dissolution of the cell walls. The cuticle, therefore, remains adherent to the top of the gland by means of the middle lamellae. It appears clear, therefore, that the release of the cuticle is, in this case, merely an expression of a general autolysis of the epidermis. This conclusion is strengthened on comparing the behavior above with that of the following.

Opuntia sp.[5] (figs. 12 to 15). The glands of this species are exceptionally large for the cylindropuntias. Usually only one occurs on an areole, though two may be found. The gland is cylindrical, and flat-topped or slightly dished. We are unable to find, in any of our preparations, an apical projection, such as Ganong figures in his paper above cited, though such a transitional condition as between the nectary and the thorn may well occur. That tissue which occupies the whole structure above the very short neck is readily divisible into two zones. The lower, occupying the much greater bulk, is composed of elongated thin-walled elements, among which are scattered isodiametric idioblasts containing small aggregates of calcium oxalate. The upper part, doubtless the proper secretory tissue, occupies a shallow zone (fig. 12, *g*) at the top of the gland, and is composed of spherical thick-walled cells with dense contents. Calcium oxalate accumulates here in large amounts in the moribund gland. Cutinization of the epidermis is confined to the outer wall, and this is not very thick. The radial and inner walls are uniformly thin. The manner in which the cuticle is set free is seen with the greatest clearness in the preparation from which fig. 13 was made, in which the thin remnants of the secondary membranes are to be seen in a state of collapse and incompleteness, empty of contents save a granule or two, and attached, but only loosely, to the arched cuticle. The middle lamellae cannot be seen except over the area from which the cuticle has not yet been released (*a*, fig. 13). Here they may be observed, as also the secondary membranes, in a

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[5] No. 46, Lloyd, Cacti of Northern Zacatecas. This species is very similar if not identical with *Opuntia tunicata* (Lehn) Link and Otto (No. 24, Lloyd, Cacti of Northern Zacatecas).

semi-disorganized condition with no protoplasm visible. With the dissolution of the epidermis, the superficial glandular cells become rounded out (fig. 14) and, it seems probable, now begin to secrete nectar.

After the cuticle is completely released, there is, according to the above account, little or nothing to be seen of the remains of the radial walls clinging to the cuticle. This circumstance makes it practically impossible, when the gland is viewed merely as a solid object, to infer the manner in which the cuticle has been set free. It is, however, clear, from our preparations, that the case is entirely different from that of the better known type of gland, already referred to, in which splitting away of the cuticle allows the accumulation of the secretion between the cuticle and the otherwise unaffected cell or cells to which it belongs.

With the advance of secretion there is a gradual disintegration of the glandular cells at the apex of the tissue in this and in the other described species. The uppermost show this first in their collapse, and in the disorganization of their contents. At the same time, there is a large accumulation of calcium oxalate, due, it is probable, to the katabolism of the proteins or sugars. The whole structure finally becomes indurated and shrivels.

General considerations. It has been repeatedly noticed in all our preparations that those radial walls which are seen on edge in longitudinal sections are always oblique, as if their inner edges had been displaced toward the apex of the gland, as indicated on the left extremity of fig. 13. Either shrinkage of the outer epidermal membrane, or a slight increase in the volume of the gland, would account for this. The latter appears the more probable, since an accumulation of sugars or other solutes would serve to attract water from the tissue below at the base of the gland, fed by terminals of the vascular system (figs. 1, 9).

A further and very curious feature of these glands, first noted by the junior author, is the behavior of the freed epidermal membrane upon dehydration. If a strip of this membrane, attached at one end and lying in water, is irrigated with alcohol, it curls away from the gland, just as do the peridial membranes in the aecia of Gymnosporangium.[6] If, however, a median longitudinal section of a gland, with the epidermal membrane attached at both extremities, is similarly treated, it is seen that it lengthens and, in consequence, forms a deeper arch. One measurement showed that a membrane which was 10.5 units in length in water, lengthened when dehydrated to 11.6 units, an increase in length of 9 per cent.

Without attempting an explanation of this peculiar behavior, it is pertinent to observe that, supposing the drying out of the epidermis to cause expansion of the cuticle, one might invoke this to explain the tearing away of the cuticle from the epidermal cells. That such an enlargement does occur is a matter of observation, but results, not in consequence of the accumulation of secretion, but rather upon exposure of the apex of the gland to the air when it pushes out from the pad of trichomes within which its earlier development occurs. By that time however the dissolution of the epidermal cells is usually well along, and in view of the positive evidence which we have advanced in support of our explanation, it is scarcely necessary to say more than that it is probable that only very slight mechanical results may be expected, and these only after the membrane has been partially released by the disorganization of the cells. Such results can be of only secondary importance.

The three glands above described present in common the phenomenon of the disorganization of the epidermal cells, setting free the outer wall to form a chamber for the reception of the nectar at the top of the gland. Excepting in *Mamillaria at the beginning of secretion only* that which appears to be a free cuticle overtopping the gland is in reality the whole outer cell wall or its remains. The whole process is evidently the result of digestion of the uncutinized cell walls, accompanied by digestion of the remaining constituents. The inference seems justified that, even in *Mamillaria*, when the cuticle alone is set free, this is permitted by a chemical metamorphosis of the underlying cellulose, or of a part of it. This explanation we believe to be equally applicable to other glands in which a disorganization of the cell itself is not involved. Such

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[6] Lloyd, F. E. and Ridgway, C. S., Cedar apples and apples. Ala. State Dept. Agric. Bull. 39, 1910.

metamorphosis as a source of sugars which, by virtue of their position without the gland, furnish the conditions for the further withdrawal of water, has been suggested by Pfeffer.[7] This same condition might very well be thought as acting to cause a change in the condition of the protoplast whereby the semi-permeability of the plasmatic membrane to sugars would be altered, and so make the exosmosis of sugars possible, since the actual excretion of these substances, in addition to that of water, does take place.[8]

The cases before us furnish additional examples of a type of nectar gland in which the excretion of sugars (and of other substances in less quantities) is preceded by the breaking down of one or more cells. The prototype is that curious nectar gland described by Zimmerman[9] in one of the tropical Loganiaceae, *Fagraea*. In this gland the branching duct results from the breaking down of the so-called "protoderm" cell, only after which, it would seem, the secretion of nectar commences. It is entirely probable that the operation of thus forming the duct results in a supply of osmotically active substances comparable to those which are present in the nectar-gland of the Cactaceae in consequence of the digestion of the epidermis. It may be further argued with certainty that the first fraction of the exuded nectar would be found to contain a greater proportion of proteins than the latter.

A further example has recently been described very briefly by Dümmer[10] in *Platycerium*, in the fronds of which lysigenous pockets are formed, either beneath the epidermis or involving it. In the latter case, the condition simulates that which we have described. It is not clear from Dümmer's account that the exudate escapes without a breaking down of the epidermis. In the event that it does, it seems more likely that the stomata furnish a path of escape than that it passes through the walls of the unchanged epidermal cells.

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[7] Physiology of plants, **1**: p. 283.

[8] On this see Livingston, B. E., The rôle of diffusion and osmotic pressure in plants. Chicago, 1903.

[9] Through Haberlandt, Physiologische Pflanzenanatomie, 4th ed., p. 462.

[10] Dümmer, R., Grape sugar as a secretion in *Platycerium*. Ann. Bot., **25**: 1205–1206, Oct. 1911.

This type of nectar gland stands in contrast with that from which the exudate is set free either directly from the free surface of the secreting cells, as appears to be the case in *Vicia* (Stockard[11]); into preformed ducts (as in certain monocotyledons, Schniewind-Thies[12]), into intercellular spaces as a normal procedure (*Pteridium*, Lloyd[13]) or abnormally, in a similar situation (in the case of honey dew, Bonnier[14]). Of the latter condition and, as pointed out in many instances by Bonnier, not in any way connected with insects, an especially striking example has recently come to our attention. In 1910 a lot of plants of three species of *Manihot*, which furnish the rubber known as Ceará, were cut off at the ground and brought into the greenhouse, where they were allowed to lie on a bench. Two species had produced fruit, from the pericarp of which large droplets of nectar were discovered to exude, this a month or more after the plants had been harvested. The plants lived for a year or longer, without any attention whatever, and in the course of several months produced new shoots and leaves, from the petioles of which a great deal of nectar exuded. Both in this situation and on the surface of the fruits, the nectar found escape through the stomata. Some smaller plants of two species *Manihot glaziovii* and *M. piauhyensis*, are now growing in pots, and these are regularly secreting nectar from the younger internodes. We have examined the tissue presumably involved, namely, that which lies beneath the point of issuance of the nectar, and have found no anatomical changes or structure correlated with secretion.

In such situations, and no less in the type of glands which physiologically are indentical with the fortuitous nectar glands of *Manihot*, the initial escape of osmotically active materials is difficult to account for except on the theory of chemical change in

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[11] Stockard, C. R., Cytological changes accompanying secretion in the nectar-glands of *Vicia faba*. Bull. Torr. Bot. Club, **33**: 247–262, pl. 10–11, 1906. (Contr. Dept. Bot. Col. Univ. no. 227.)

[12] Schniewind-Thies, J. Beiträge zur Kenntniss der Septalnectarien. Jena. 1897.

[13] Lloyd, F. E., The extra-nuptial nectaries of the common brake, *Pteridium aquilinum*. Science, N. S., **12**: 885–890. June 7, 1901.

[14] Bonnier, Rechèrches expérimentales sur la miellée. Rev. Gen. de Bot., **8**: no. 85, 1896. (Ref. in Bot. Centralb., **69**: 82–83, 1897.)

the cell wall, it may be more particularly the primary wall. Research in this direction would not be amiss.

SUMMARY

The nectar glands of the Cactaceae, so far as they may be represented by *Echinocactus*, *Opuntia* and *Mamillaria*, are of a type in which secretion of nectar is preceded by digestion of the epidermal cells, and consequent disorganization of their walls and contents. This sets free the *whole outer wall of the epidermis*, from which, however, the cellulose element may disappear. There is thus formed a chamber for the reception of nectar at the top of the gland. The rupture of the membrane sets the nectar free. In *Mamillaria* and perhaps *Opuntia* at first only the cuticle is thrown off, but this is only an early expression of the disorganization of the whole epidermal tissue capping the gland.

EXPLANATION OF FIGURES

1 A mature nectar gland of *Echinocactus* sp., in median longitudinal section.

2 A portion of the apex of the same gland, showing the somewhat extensive intercellular spaces, and the breaking away of the radial walls.

3 A portion of the same, with the details of secondary walls and contents of the cells presented in greater detail. The figure is taken from the edge of the area of dissolution of the cells. Droplets of oil are shown in the middle epidermal cell.

4 Epidermal cells in tangential view, to show the irregularity of cutinization.

5 The cutinized strands of the inner walls of the epidermis.

6 *Mamillaria* sp. (Lloyd, No. 31). The development of the trichomes.

7 The formation of cork of epidermal origin beneath the trichome pad.

8 Early cork divisions in the epidermal and sub-epidermal cells. *e*, Epidermis.

9 Longitudinal section of the gland of *Mamillaria* (Lloyd, No. 40). *g*, Glandular tissue proper; *p*, Thin-walled prosenchymatic tissue; *e*, Cork tissue forming the floor of the areolar pad.

10 Apex of the same gland showing the separation of the cuticle from the apical epidermal cells.

11 Edge of the area of dissolution in the same, at a later stage.

12 Gland of *Opuntia* (Lloyd, No. 46). Letters as above.

13 The disintegration of the epidermis in the same.

14 and 15 Edges of areas of dissolution at a later stage.

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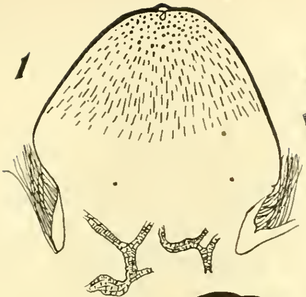

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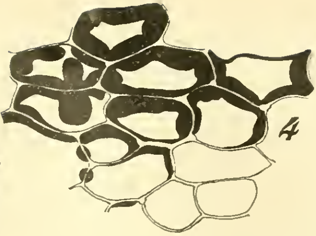

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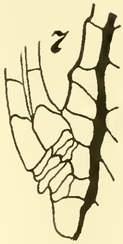

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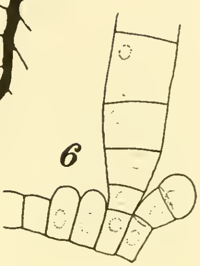

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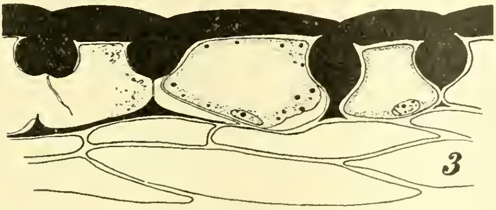

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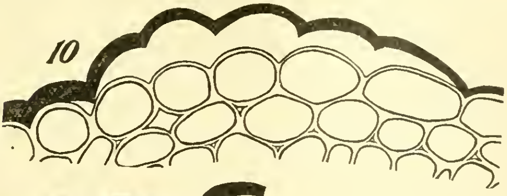

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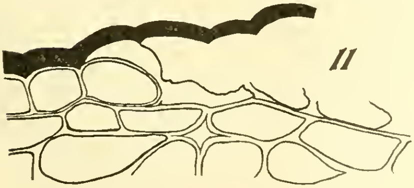

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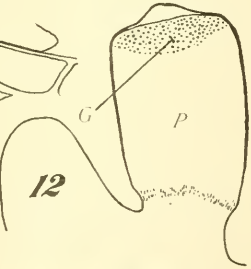

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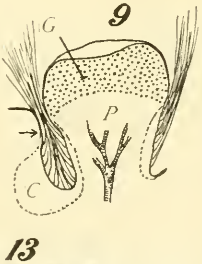

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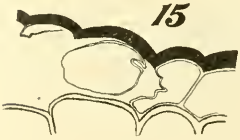

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NOTE ON THE DEVELOPMENT OF TRICHOMES AND AREOLAR CORK

The floor of the sulcus or areole from which the nectar gland arises is thickly clothed with trichomes, each consisting of a single row of cells. They are very long, of uniform thickness, and increase their length by the elongation of new cells produced basipetally. When however the trichomes cease to increase in length, the epidermal cells from which they arise continue to divide (fig. 7) below the level of their outer walls, this forming a periderm-like layer of cells, which are more or less cutinized. Similar divisions, parallel to those in the epidermis then appear in the underlying parenchyma (fig. 8), or, as it may be in some species, collenchyma, adding more, but not uniformly or completely suberized, tissue to the imperfect cork already formed by the epidermis. There may thus be developed a corky pad of considerable thickness (fig. 9, *c*), consisting of very numerous thin-walled, collapsed and imperfectly suberized cells forming the floor of the areole.

The impression is created, by this peculiar mode of development, of concrescence of the trichomes as they become older at the basal portions. The proper interpretation appears to be that, when the trichomes reach the limit of development, the epidermis, which has contributed to the trichome development, now forms a cork layer, this being increased in thickness by the removal of the periderm divisions to the underlying tissue. Figs. 7 and 8, which were taken from the edge of the trichome bearing cork pad in a species of *Mamillaria*[15] show clearly that the epidermis is involved in cork formation[16] as first noted by Schleiden.[17]

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[15] No. 31, Lloyd, Cacti of Northern Zacatecas. National Herbarium.

[16] F. A. Wolf has observed a similar behavior in the formations of cork islands in *Opuntia lindheimeri*. Ann. Myc. **10**: 113–134, 1912.

[17] Through Solereder, Sys. Anat. d. Dicot.

A ROTATING TABLE FOR STANDARDIZING POROUS CUP ATMOMETERS

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Since the efficiency of the porous cup atmometer[1] depends largely on the standardizing of each cup before and after its use, the method used in standardization is exceedingly important. As heretofore described, the operation consists in determining the relatives rates of water loss from the cups to be standardized and from a standard evaporating surface. The method of standardizing to an open dish of water (Plant World **13**:111, 1910) has proved unsatisfactory and has been abandoned. The discussion of this proposition will be deferred to a later date. The only standard now available is either a porous clay cup or a paper cylinder (Plant World **14**: 281, 1911). In either case the relative rates of water loss, under the same surroundings, must be determined for several time periods. It has been our practice to arrange the series of cups to be standardized (mounted on glass tubes in small-mouthed bottles, which are filled at reading to a file mark on the neck) about 50 cm. apart on a clean floor or table, trusting that the convection and other currents of the surrounding air would be sensibly similar about the various instruments.

Where operations are carried on in the open, there is no objection to this method, which is still in use at the Desert Laboratory for the hundreds of standardizations necessary there for each year's

[1] The instrument was devised in its essentials by Babinet (Compt. rend **27**: 529–30. 1848). It was independently devised by A. Mitscherlich (Landw. Versuchsstat, **60**: 63, and **61**: 320. 1904), and by the writer (Publ. 50, Carnegie Institution, 1906). The literature of this form of atmometer is presented in Plant World **13**: 111–118. 1910. On a modification of the instrument, see Transeau, E. N., A Simple Vaporimeter, Bot. Gaz. **49**: 459–60. 1910.

For later literature see: Plant World **14**: 96–99. 1911; Bot. Gaz. **52**: 417–438. 1911; Plant World **14**: 281–289. 1911.

work in transpiration and climatology. The only critical points to be considered in connection with work in the open have to do with the questions whether or not the platform chosen for the tests is freely exposed to wind movement in all directions and whether the air moving over it is as free from dust as is possible.

But weather conditions so frequently preclude the standardization of these instruments out of doors, especially in any but the most rainless climates, that the indoor method has been resorted to in many instances. All cups used as standards at Tucson, and all standardized cups furnished to other workers are now standardized within doors, at the Laboratory of Plant Physiology of the Johns Hopkins University.

Since the relative importance of convection currents in the air about the cups is very greatly magnified as soon as the general sweeping action of the horizontal air movement (which is so nearly always effective out of doors) is checked, the problem of the equalization of such currents is of prime importance for indoor work. Also, especially in artificially heated rooms, there is a high degree of probability that, during any period of observation, one portion of the room may be warmer or cooler than another. Also, it is desirable to increase the rate of evaporation in the house by the use of an electric fan, a procedure which could not possibly furnish the same air movement to all of a series of stationary cups.

It is practically impossible to place two or more instruments in a room so that they will all be exposed to the same conditions of temperature, humidity and air movement. The problem had to be attacked from the other side, it was necessary to devise means by which, with various parts of the room exhibiting various aërial conditions, all cups should nevertheless be subjected to exactly the same series of changes during any time period. This has been accomplished by the use of a rotating table, near the outer margin of which the instruments (in their bottles) are placed. As the table rotates, one cup after another marches into and out of any given region of the surrounding air, and, with every rotation, each cup returns rhythmically to this same region. The movement of the cups tends to wipe off the vapor blanket which would hang over each one were it stationary, and, if higher rates of evaporation are requisite, an electric fan may furnish a stream of air crossing the table in any direction. The apparatus is so satisfactory for standardizing cups to standard cups, and so simple in construction, that it seems to warrant brief description.

The table is 8 feet in diameter, turned about once per minute by means of a small motor belted to a reducing gear.[2] The bearings are practically without friction, being formed from two ordinary rear bicycle hubs, usually cheaply and easily procured. Riveted through some of the spoke holes, to the lower flange of the lower hub (fig. 1, *A*) is a $\frac{1}{4}$-inch grooved pulley, 4 inches in diameter, this taking the place of the discarded sprocket wheel. This pulley is reached by a leather belt from the reducing gear, running beneath the table.

To the upper flange of the lower hub (fig. 1, *B*) is similarly riveted a $\frac{1}{16}$-inch steel plate, 6 inches in diameter, perforated near its margin for four stove bolts (fig. 1, *E*), equally spaced. Suspended below this plate is a second and larger one (12 inches in diameter, fig. 1, *C*), unattached save by means of the four bolts just mentioned, which screw into properly tapped holes. The larger plate has at its center a circular opening large enough to allow of its being slipped into place over the upper flange, before the first plate is attached. It bears near its margin twelve equally spaced perforations, tapped to take stove bolts (fig. 1, *e*).

The radial arms of the table (fig. 1, *D*) arranged like the spokes of a wheel, are of $\frac{3}{4}$ by 3 inch wood. Their inner ends are laterally chamfered so as to allow them all to fit together about the lower hub. They are thrust horizontally into the space between the two plates above described, some being cut a little to allow for the four suspending bolts, these bolts are then tightened with a screw driver, and the lower plate thus raised clamps their inner ends into space. After proper adjustment of the arms, a bolt with a washer (fig. 1, *e*) is passed through a suitable hole in each wooden arm, a short distance beyond the margin of the upper plate, and is screwed tightly into the corresponding tapped hole

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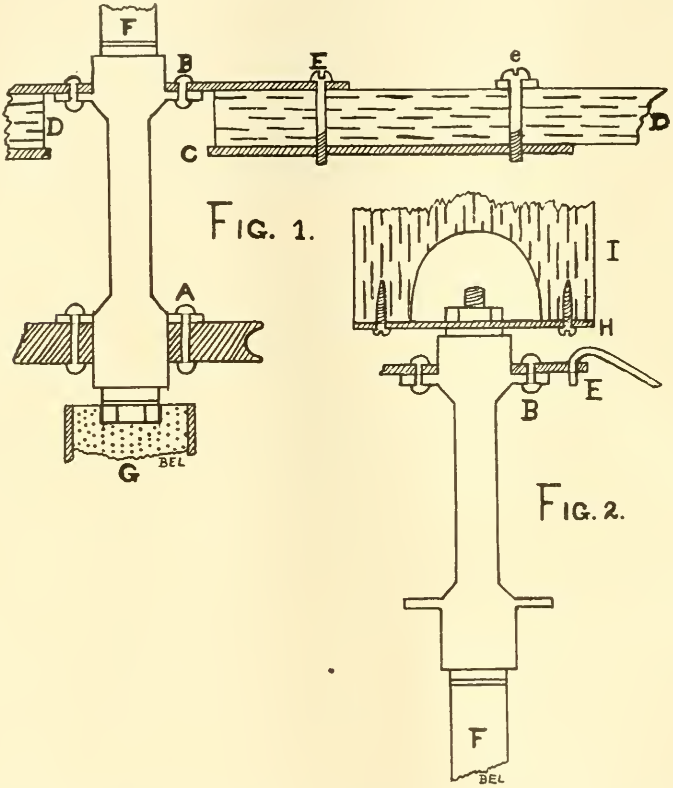
[2] By far the best gear that I have found on the market—suitable for any physiological purpose for which such device is requisite—is furnished by the Eberbach and Son Company, Ann Arbor, Mich.

in the lower plate. The arms are thus rigidly attached to the lower hub.

The vertical axis is formed from a steel rod ($\frac{3}{4}$-inch in diameter and 2 feet long), drilled and tapped at either end to receive the short free end of the ordinary bicycle axle bolt. After the bear-



Arrangement of Bicycle Hubs and Attachments for Rotating Table

Fig. 1 Lower hub: *A*, pulley; *B*, upper plate, riveted to hub; *C*, lower plate, attached to *B* by bolt *E*; *D*, wooden arm, attached to *C* by bolt *e* and clamped between *B* and *C*; *F*, axis extension; *G*, top of pipe support with socket for end of axis.

Fig. 2 Upper hub: *B*, plate riveted to hub and with holes (*E*) for attachment of guy-wires reaching to ends of wood arms; *H*, plate attached to upright upper support from ceiling (*I*) and serving to fix upper end of axis.

ings have been adjusted, this rod is attached to the axle of the lower hub, thus extending it upward (fig. 1, *F*). The upper hub is similarly attached by screwing the end of its axle into the upper end of the rod (fig. 2, *F*). The only necessary modification of the upper hub is the riveting to one of its flanges of a steel plate 3 inches in diameter (fig. 2, *B*), bearing near its outer margin twelve $\frac{1}{4}$-inch openings, equally spaced. Into these openings hook the bent ends of steel bolts (fig. 2, *E*) which connect, by turn-buckles and second bolts, to guy wires that reach to screw eyes near the outer ends of the wooden arms below. Turn-buckles were difficult to obtain at a reasonable price and common wood-saw rods procurable for a few cents apiece were resorted to. The wire loops at the ends of these were discarded and the heads of the bolts removed. The right screw bolt was bent to hook into the openings just mentioned and the other of the pair was perforated near its cut end to receive the wire guy. By tightening the turn-buckles, the wooden arms are brought into alignment, the outer ends being raised a little above the level, to put strain on the entire truss system and thus give the table rigidity even without a load.

The table rests on a standard of iron pipe, screwed firmly to the floor at its center and at the end of each of its four legs. In the upper end of this standard (a six-way casting into which the four legs screw laterally and the centerpiece below, is a plug of Babbitt metal (fig. 1, *G*), poured around the hexagonal nut which terminates the lower bicycle axle. The hexagonal cavity thus formed is just deep enough to receive the nut, the axle not being allowed to project.

To fix the upper end of the table axis, a steel plate (1 inch wide and 4 inches long, drilled at its center to fit the axle bolt, fig. 2, *H*) is slipped over the latter and drawn into place against the cone of the bearing by means of a nut above. This plate is fastened by two wood screws to the end of a wooden thrust arm (fig. 2, *I*) which extends upward and is fixed to the ceiling of the room. The lower end of this member is cut out at its center leaving a U-shaped opening to allow of the manipulation of the nut above the terminal plate. The vertical arm is held rigidly in position by means of four guy wires to the ceiling, provided with turn-buckles.

It is unnecessary to floor over the entire surface of the table, since the instruments must all travel in the same circle, and the spaces between the wooden arms of the table here described are closed merely at the margin, by screwing to the arms twelve properly fitted pieces of $\frac{1}{2}$-inch wood, 12 inches wide. The margins of these are not curved. The arms project a little beyond the twelve angles, and bear screw-eyes for the fastening of the supporting guywires. A circle is marked on the continuous surface thus produced, having a radius such that when the bottles now in use stand against the line the centers of the cups will describe a circle with a radius of 115 cm.

In placing the instruments upon the table, it is to be remembered that every cup should receive the same amount of influence due to the trailing vapor blanket which emanates from the next preceding one. With ordinary room temperatures and the stirring action of an electric fan, enough water is lost from the type of cup now in use to allow of daily readings.

BOOKS AND CURRENT LITERATURE

A Yosemite Flora.—The authors of this flora[1] claim in their preface, with truth, that "the Yosemite National Park is perhaps the most delightful region in all the world for the study of plant life." In support of this assertion they set forth the remarkable diversity of ecological conditions there to be found in a comparatively limited area, affording congenial environments to an extensive and varied flora. The area of the Park is 1124 square miles, and upon it grow at least 1200 species and varieties of ferns and flowering plants, almost exactly one-quarter of the number treated in the last edition of Gray's Manual for the whole northwestern and central States of the Union and adjacent Canada.

The scenic attractions of the wonderful Yosemite Valley draw to it a continually increasing concourse of summer visitors, to most of whom the great trees, the beautiful or curious flowers of the shrubs and herbs are all new and strange. It cannot fail that many will desire an introduction to these interesting neighbors, to learn their names, and something of their family relationships, and will welcome a book which shall afford them this information. Always provided that they are able to understand the book; for not many will have the botanical knowledge needed for a technical manual, would, indeed, be repelled by it.

It is this class of readers that the authors have had primarily in mind in preparing their book, successfully striving to make it one that shall attract the amateur and the lover of flowers, and at the same time not repel the botanist. The descriptions of genera and species are made as simple as possible, but they are accurate and will correctly guide the reader to the identification of his plant. The keys to the tribes of the Compositae, and to such difficult genera as those of the Cruciferae and the Umbelliferae, which if founded on technical characters usually employed could not be used by untrained readers, are here models of how rough places may be made easy. They are, it is true, entirely artificial, and give prominence to characters on which the systematist

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[1] Hall, Harvey Monroe and Hall, Carlotta Case, A Yosemite Flora, a descriptive account of the ferns and flowering plants of the Yosemite National Park. Pp. 282, pls. 11, figs. in text 70. San Francisco: Paul Elder and Company, 1912. ($2.00.)

is not accustomed to place much reliance, but they enable the novice to find his plant, while he would close an ordinary manual in despair. The authors have very sensibly omitted the Gramineae, the Cyperaceae, and the Juncaceae, families having little attraction for amateurs.

The book begins with a sketch of the plant ecology of the Park, followed by a short morphological summary explanatory of the organs of plants, the various forms of them, and definitions, rendered more plain by figures, of the more important terms used in describing them. The method of classification and the use of keys is thus explained. Only sixteen page are occupied with these preliminaries, but so clear is the style that a careful perusal will fit any intelligent reader for the use of the keys and descriptions of the Flora. A glossary provides further help, as also do the numerous text figures.

The size of the book, 7½ by 4½ inches, and the flexible leather binding make it convenient to handle and easy to carry. The print is clear and good, and the attractiveness of the volume is enhanced by the plates, which are in part ecological, and in part plant portraits, The authors are to be congratulated on their success in the accomplishment of a difficult task, the preparation of a thoroughly satisfactory popular Flora, and visitors to the Yosemite, or, for that matter, to the central range of the Sierra Nevada, on the publication of a book wherewith they may easily obtain an introduction to the plants about them.—S. B. Parish.

Chemical Phenomena in Life.—Hampered by a language not his mother-tongue, limited by the compass of a small octavo volume, and possessed of more than all the knowledge crowding a thousand and more pages, the brilliant Professor of Plant Physiology at Prague has nevertheless given us in Chemical Phenomena in Life a masterly exposition of the present status of biochemical thought and knowledge.[1] Czapek is one of the most interesting figures in plant physiology today, a man of prodigious industry, as proved by his Biochemie der Pflanzen; of fertile ideas, as shown by his own experimental work; and of synthetic mind, as displayed in this small volume. Of sanguine temperament, he sometimes accepts as proved what, in his own and others' work, lacks confirmation: and yet is it not true that the real leaders in science, as well as elsewhere, are those whose minds and souls are on fire and not merely conservatively warm? Czapek's little book expounds, as well

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[1] Czapek, Fr., Chemical Phenomena in Life. Pp. 152. New York: Harper and Brothers, 1911. ($0.75.)

as the state of our knowledge now permits, the physical conditions and chemical processes in cytoplasm and nucleus of living cells. The vocabulary of colloid and enzym chemistry is special; but though an unavoidable obstacle to the unaccustomed reader, it is greatly reduced by careful definition. The quantity of mathematics also is moderated to the absolutely indispensable, though to a good many kinds of botanists there may still seem to be rather much. This book should serve a double purpose: first of giving to botanists of other sorts a clear concise statement of the aims and attainments of the chemical physiologists; and second of indicating to that part of the general public which still does any solid reading that biology, like chemistry and physics and by means of them, is trying to become an exact science.—G. J. P.

GERMINATION OF A PARASITE.—Biological studies of holoparasites reveal many interesting facts. *Aeginetia indica*[1] differs from other known forms in several respects. Its seeds will not germinate in soil, water, or in a moist chamber but do so readily when in contact with the roots of a variety of vascular cryptogams, gymnosperms and angiosperms. The seedlings will develop, however, only on certain species of monocotyledons. *Orobanche* and *Lathraea*, related genera, germinate only in the presence of the proper host. The seeds of other phanerogamic parasites (*Cuscuta*, Santalaceae, Rhinanthaceae and Loranthaceae), germinate under the same conditions which are favorable for plants in general. Kusano's experiments with seeds of *Aeginetia*, wrapped in one or more folds of paper, give evidence that the root of the host must excrete some diffusible substance which stimulates germination. He was not, however, able to report the presence of any specific substance. The etching of marble by the roots of seedlings has everywhere been used as a classic proof of the excretion of acids. Czapek's recent experiments, however, throw grave doubts upon the validity of this proof. In fact, the whole field of investigation on root excretion leaves much to be desired as yet. The "hair tendrils," morphologically trichomes and functionally root hairs and tendrils, and their penetration between the epidermal cells, which is admirably illustrated in the plates accompanying the text, appear never to have been described in phanerogamic parasites. —FREDERICK A. WOLF.

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[1] Kusano, S., Further Studies on *Aeginetia indica*. Beihefte z. Bot. Centralblat **24**: 286–300, pl. XI–XII. 1909.

NOTES AND COMMENT

In August, 1911, The Plant World sent a circular letter to a number of botanists asking them to state what they considered to be the one or two most important contributions to botanical science published within the preceding year or two. The letter stated that the replies would be published, but that the names of those who answered would not be used in connection with their replies. The list of men interrogated included both foreign and American names, selected with a view to representing every shade of botanical interest and activity. Each person was left free to mention a single journal article or an extended text-book, to choose a contribution that was brief and novel or one that was extended and compilatory.

We realise fully the many considerations which have made it difficult for our correspondents to give an answer for the entire science, now so highly specialised, and an answer that would seem just as satisfying several years hence as it may seem at the present time. Our question was broached with the feeling that considerable interest might attach to the collective replies of a large number of men living in widely scattered localities and pursuing a diversity of interests. Following are the works which have been mentioned; each of them once only unless otherwise indicated by the figures in parentheses which follow.

Winkler, work on Graft Hybrids (6).
    Winkler, H. Über die Nachkommenschaft der Solanum-Propfbastarde und die Chromosomenzahlen ihrer Keimzellen. Zeitschr. f. Bot. **2**: 1–38, 1909. Winkler, H. Über das Wesen der Propfbastarde. Ber. d. Deut. Bot. Gesell. **28**: 116–118, 1910.

Smith, work on Crown Gall (5).
    Smith, Erwin F. Crown Gall of Plants: Its Cause and Remedy. Bur. Plant Ind. Bull. 213, 1911.

Johannsen, work in Genetics (2).
    Johannsen, W. Elemente der exacten Erblichkeitslehre, 1909.[1]

Coulter and Chamberlain, work on morphology of the Gymnosperms (2).
    Coulter, John M. and Chamberlain, Charles J., Morphology of Gymnosperms, 1910.

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[1] Two of the works mentioned were published more than two years ago, but they have not been discarded.

Bateson, W. Mendel's Principles of Heredity. Cambr. Univ. Press, 1909.

Berthelot, D. and Gaudechon, H. Synthèse photochimique des hydrats de carbone aux depens des éléments de l'anhydride carbonique et de la vapeur de l'eau, en l'absence de chlorophylle; synthèse photochimique des composés quaternaires. Compt. Rend. **150**: 1690–1963, 1910.

Dixon, H. H. Transpiration and the Ascent of Sap. Prog. Rei. Bot. **3**: 1–66, 1909.[2]

Lawson, A. A. Nuclear Osmosis as a Factor in Mitosis. Trans, Roy. Soc. Edinb. **48**: I, 7, 1911.

MacDougal, D. T. and Cannon, W. A. Conditions of Parasitism in Plants. Carn. Inst. Wash. Publ. 129, 1911.

Marchal, El. and Em. Aposporie et Sexualité chez les Mousses III. Bull. de l'Acad. roy. de Belgique. Cl. des Sciences, nos. 9–10, 1911.

Nemec, B. Das Problem der Befruchtungsvorgänge. Berlin, 1910.

Palladin, work on respiration, Palladin. W. and Stanewitsch, E. Die Abhängigkeit der Pflanzenatmung von den Lipoiden. Biochem. Zeitschr. **26**: 351–369, 1910. Palladin, W. Zur Physiologie der Lipoide. Ber. d. Deut. Bot. Gesell. **28**: 120–125, 1910.

Pearson, H. H. W. Papers on the Morphology of Welwitschia. Phil. Trans., 1909. Ann. Bot. **24**: 1910.

Renner, O. Beiträge zur Physik der Transpiration. Flora, **100**: 451–547, 1910.

Scott, D. H. Studies in Fossil Botany. 2d ed. London, 1909.

Seward, A. C. Fossil Plants **2**. Cambr. Univ. Press, 1910.

Shantz, H. L. Natural Vegetation as an Indicator of the Capabilities of Land for Crop Production in the Great Plains Area. Bur. Pl. Ind. Bull. 201, 1911.

Strasburger, E. Sexuelle und apogame Fortpflanzung bei Urticaceen. Jahrb. Wiss. Bot. **47**: 1910. Über Geschlecht bestimmende Ursachen. Jahrb. Wiss. Bot. **48**: 1910.

Nothing is more noticeable among the assembled replies than the diversity of opinion which they reflect; only four works having been mentioned by more than one man. Of the six men who mentioned Winkler's work four are physiologists and two are morphologists; their nationalities are respectively British, German, Austrian, Japanese, and American (2). Of the five men who mentioned Smith's crown gall work one is a pathologist, one an algologist, one a morphologist, and two physiologists; all of them being Americans. Of the two men who mentioned the work of Johannsen one is a physiologist, the other an ecologist; one being Swiss the other an American. The two men who mentioned Coulter and Chamberlain's work on the Gymnosperms are both American morphologists. The personnel of our correspondents offers no other observation more interesting than the fact that no Euro-

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[2] Two of the works mentioned were published more than two years ago, but they have not been discarded.

pean mentioned any extra-European work, while eleven Americans mentioned extra-American work. Four physiologists mentioned non-physiological work, and one morphologist mentioned non-morphological work. None of our correspondents mentioned taxonomic work, and none of the taxonomists to whom our inquiry was addressed replied to it.

The net result of the responses secured is that a healthy difference of opinion exists among botanists as to what current work is of the most importance, and this difference of opinion does not seem to be determined by the limits which bound the several sections of the science. In fact one of the most refreshing phases of our replies is the extent to which men have mentioned work outside their own special fields, and also the several cases in which men have mentioned the work of other botanists with whom they are well known to have been in sharp competition for the freshest laurels in certain restricted fields of endeavor. We are sorry not to be able to point out a geographical catholicity among botanists as satisfying as that which exists between the several departments of the science.

NOTES ON THE PRESENT STATUS OF PALEOBOTANY

EDWARD WILBER BERRY

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Paleobotany aims to understand the succession of floras that have existed on the globe, their composition, evolution, and distribution. The science of botany becomes then the study of the flora of but one geological period, the present, while paleobotany is the study of the floras of all geological periods. Taxonomy and morphology combined will eventually supply adequate data for phylogeny, or the completion of the natural system of plants, the ultimate goal.

Our knowledge of nearly all the great groups would be very one-sided if we knew only their end products in the existing flora. To the Thallophyta and Bryophyta the fossil record has furnished but meager data beyond showing that the former are exceedingly old and were never very different from what they are today, while the latter are apparently absent except in comparatively recent geological times. Hence it is extremely unlikely that paleobotany will ever shed any light on the ancestors of vascular plants.

The Sphenophyllales, generalized types extinct since the Paleozoic, represent the end product of the ancestral stock which earlier gave rise to the Equisetales and more remotely to the Lycopodiales. We know of the existence of the Pseudoborniales, which are intermediate between the Sphenophyllales and the primitive Calamites, but need a knowledge of their internal structure. We also need impressions showing the character and habit of those supposed Sphenophyllum-like plants which bore the structural cones known as Cheirostrobus. We have had much anatomy of the Botryopteridae or so-called Primofilices and would welcome the correlation of a large number of genera founded upon petiolar anatomy with material showing the external form and consequently the geological range of these ancient ferns. The remarkable results of the recent study of the Pteridospermae in the light of their seed habit has rendered scarcely any Carboniferous fern inviolate and it would seem wise to heed the warning of Professor Chodat of Geneva and take a new inventory of the structure and especially of the affinities of the different members of the so-called Cycadofilicales. Among the Equisetales we need a more extensive knowledge of the Archaeocalamites group and of the Triassic Neocalamites as well as of the ancestral Equisetums of that age. Among the Lycopodiales we have demonstrated the complexity and almost seed bearing habit of some of the members of the Paleozoic stock, but a knowledge of the Mesozoic representatives of this phylum would fill a great gap in our knowledge. An occasional hint like the Lepidodendron-like cone from the Rhaetic recently described by Professor Nathorst suggests that many interesting and important facts are hidden in the Triassic rocks. Among the Filicales we not only need such work as that of Kidston and Gwynne-Vaughan on the Osmundaceae but we need to outgrow the necessity for form-genera, especially in the post-paleozoic floras. The progress of our knowledge of the Cycadophyta is being well looked after by Nathorst abroad and Wieland in this country, while Jeffrey is making momentous contributions to the anatomy of the Mesozoic and recent Coniferales. The ancestry of the Angiosperms is still a baffling problem in spite of the seductive Cycadeoidea-theory based upon Wieland's excellent work. Doubtless it will remain baffling until we have a better acquaintance with the anatomy of the existing species and a rational natural classification.

Above all things we need individuality in morphological and phylogenetic work and a greater immunity from infection by the prevailing fashions in theory. The path that science has trod is lined with the graves of theories, and it seems to me that at the present time we are too uncritical, too ready to pay tribute to workers who have made splendid contributions to knowledge by our whole hearted acceptance of their theoretical deductions, when we might perhaps be more useful in assisting in the burial of their theories. We need also a more philosophical attitude toward morphological entities and a realization that they are the end products of an evolution and not rigid unvarying morphological species any more than are the species of the systematist.

Paleobotany has shown the independent development of heterospory and even of the seed-habit in unrelated Pteridophytes, it has shown the development of secondary growth in various unrelated orders. Why then must a leaf be a morphological entity throughout the vegetable kingdom instead of a physiological entity?

The study of fossil plants is most properly a branch of botany. It is on the other hand intimately associated with the science of geology, as has been frequently emphasized. This is especially true in the United States where the value of fossil plants as an aid to the stratigraphic geologist is perhaps more appreciated and they are certainly utilized to a greater extent than in any other country. Furthermore the funds for the study of fossil plants, in this country at least, have come almost entirely from geology, officially organized. The necessities of the geologist in his areal mapping and in the correlation of his formations make it desirable for the paleobotanical workers to name fossils which are often of but slight botanical interest or of unknown relationship. This feature of the work combined with the modern trend of botany away from the old ideals of systematic work into the realms of chemistry and physics, and the extreme specialization of its votaries as well as the narrow specialized training of botanical students in general, has served to widen the breach between botany and paleobotany, which deserted by its own mother, has grown up with its foster mother, geology.

However admirable morphological, cytological and physiological work may be, and I do not wish to be understood as depreciating this work in the slightest degree, it remains true that the average botanical student of today does not know plants as he should. Nor have the vast majority of mature workers any appreciation of geologic time or of the march of vegetation over the earth in bygone ages with which to properly orient themselves for considering phylogeny, or even morphology.

Any adequate summary of the present status of the study of fossil plants throughout the world, embracing as it does the pursuit of so many and different goals, would carry us so far afield that the ultimate analysis would lose interest, so that what follows may be taken as merely a running commentary rather than a detailed inventory, after which a few paragraphs will be devoted to pointing out some of the desirable lines of advance, more especially in North America.

Taking up the study of paleobotany by geographic divisions we will consider first our kin beyond the sea. In Great Britain the study of fossil plants has always meant little else than the study of the calcareous petrifactions of the Coal Measures and similar structural remains. Under the leadership of the late W. C. Williamson and his still abler pupil Scott, epoch making contributions have been made to morphology and phylogeny and a large number of younger workers are actively engaged at the present time in adding to the structure whose foundation was laid by Williamson. Each month furnishes gratifying proof of the activity of our colleagues in England and Scotland along the lines of work just mentioned. With the exception of Professor Seward's splendid work on the rich Jurassic flora, more particularly of Yorkshire, and of the Wealden flora of the south of England, and that of Dr. Kidston on the Carboniferous floras, the much more abundant remains of former plants preserved as impressions have been almost entirely neglected. Such attempts as have been made in the study of this class of remains have been relatively poor as compared for example with the splendid work which Nathorst in Sweden is doing, or with the work of the French paleobotanists, past and present. Without any abatement in the work along existing lines which would be deplorable, there is need for a more thorough study of British Cretaceous floras and the general student and geologist would welcome a careful description of the splendid series of Tertiary floras of that country, so long known but never adequately studied.

Crossing the channel we find the French fully maintaining the standard set by Brongniart, Saporta and Renault. The work in the latter country has nearly always been of first quality. Especially in the study of impressions French paleobotanists have been particularly happy and have given an example of painstaking comparison with modern plants which might be emulated to advantage by American workers. The reports on the floras of the various coal basins commencing with that of Grand 'Eury on the Loire basin in 1877 and followed by a number of similar reports by Renault and Zeiller form a body of literature unsurpassed for excellence, and standing at the head of the list of official publications the world around for their scientific merit in either geology or botany. The French Mesozoic and Tertiary floras have always received very full treatment, those from the Pliocene of Central France and the Eocene of the Paris basin being under active investigation at the present time by Laurent, Marty and Fritel.

In Germany, aside from the study of the Pleistocene and Recent fossil floras of the peat bogs little that is of really first quality is being accomplished, although this statement is general and there are notable exceptions. Germans since Goeppert's day have excelled in the study of fossil woods and the recent work of Gothan fully maintains their position in this field.

In the Scandinavian countries Pleistocene problems have been very fully worked out and the torch which Oswald Herr carried into the Arctic regions is kept bright by Nathorst, whose methods of work in all phases of paleobotanical investigation are especially praiseworthy.

The Austro-Hungarian monarchy, so rich in fossil plants, the home of Sternberg, Unger, Feistmantel, Ettingshausen and Stur, seems to be resting on the laurels of the past and the writer knows of no especially noteworthy work going on at the present time. Elsewhere in Europe there are a few workers in Italy, and Zalessky in Russia. In Japan there is Yokoyama and his associates. The rest of Asia and all of Africa and South America have yet to produce a paleobotanist and the same remark is true of Australia.

Finally in the United States we find much that is hopeful and much that is discouraging. The workers are too few and are buried under mountains of rapidly accumulating materials collected for the most part by the federal or the various state geological surveys. Both from a utilitarian as well as a scientific standpoint there is an assured future for the exceptional beginner in the study of fossil plants whether he turn his attention to vascular or other anatomy, to leaf impressions, or to the stratigraphic, ecologic or geographic aspects of fossil floras. The rounding out of long projected lines of work so that the results will be available for the general scientific public is eminently desirable.

Internal anatomy waits on the discovery of tractable materials like the Kreischerville lignites or the Black Hills cycadophytes. The great bulk of the remains of former vegetation will always consist of impressions of the various parts of plants. It would be criminal to neglect this class of remains for fear that we might make mistakes in identification.

Turning in conclusion to lines of work pressing for accomplishment, selection is difficult. The Cretaceous and later floras of the Interior need bringing up to date, the Canadian floras of all ages, Devonian to Pleistocene, are badly in need of revision, the Tertiary floras of the Far West and of the Gulf area are largely unknown, Alaska offers a rich field, Triassic floras are badly in need of modern treatment, and the status of our Paleozoic floras is sadly behind the times.[1]

One phase of the study of fossil plants alike disgraceful to American geology and to American botany is our lack of knowledge of the flora which immediately preceded the present one. As compared with the monumental work on the Glacial, Interglacial and Postglacial floras in Great Britain, Scandinavia, Denmark and Germany almost nothing has been done in the United States. Some few contributions to the study of our Pleistocene floras south of the terminal moraine have been made but the really important glaciated area is practically untouched, although it is known to be rich in fossil plants at certain localities and they are probably more widespread than has been imagined. A

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[1] These statements refer to published results and do not take into account work in progress by various students.

systematic paleobotanical-geological study of our northern peat bogs and old forest grounds would be most timely. Such a study would not only yield a large body of purely botanical information but would serve to establish a rational chronology with respect to the various advances and retreats of the ice sheets, would throw much light on the attendant physical and climatic conditions and would furnish a sound foundation for the study of modern plant distribution.

For example such a study ought to furnish data for determining whether secular cooling was a factor in causing advancing ice sheets and if not to what extent the influences of the continental glaciers was felt many miles south of the terminal moraines. There is some evidence that there was but slight if any lowering of temperatures in low latitudes, but until the chronology of events and the correlation of deposits is perfected we cannot know whether our southern Pleistocene floras were contemporaneous with the advances of the continental ice sheet or correspond to interglacial periods.

Such a study would not only open the way for the consideration of numerous subsidiary problems that would be sure to be raised, but it would enable us to determine the antiquity of numerous elements in the existing flora, the extent and perhaps the rate of their migrations, which in turn ought to furnish the key to the solution of numberless problems of geographic distribution and the influence of physiography upon ecology. It would also contribute data for estimating the part which certain edaphic factors, such as the increased physical and chemical complexities of soils due to ice action, had in the evolution of new forms, as well as the part taken by increased competition in lower latitudes in the van of advancing ice sheets and the reversal of conditions with their retreat.

We owe it to the rest of the world to do our duty by our native continent. Some sort of systematic attack should be made upon this problem, in which coöperative work would possibly be desirable.

THE DIGESTION OF STARCH IN GERMINATING PEAS[1]

W. RALPH JONES

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Rywosch[2] has called attention to the fact that when a pea is germinated, the disappearance of the starch content is not simultaneous in all parts, but usually takes place in a regular cell succession, beginning in the peripheral cells and passing inwards toward the vascular bundles. He has pointed out that when the starch in the peripheral layer of cells is dissolved, the osmotic pressure of these cells must be raised, and the sugar produced should diffuse inward into the adjacent cells where the osmotic pressure is lower. This diffusion should continue until the vascular bundles are reached, and the sugar is conducted away from the cotyledon.

In an attempt to gain more definite information toward an explanation of this striking phenomenon, a series of experiments was carried on during the spring of 1910, in the Laboratory of Plant Physiology of the Johns Hopkins University. The work was undertaken at the suggestion of Prof. Burton E. Livingston, to whom I am greatly indebted for his constant interest and his helpful suggestions. Although little definite knowledge of the causal factors here involved has been obtained from these experiments, yet considerable advances have been made toward that dynamic appreciation of these processes which is fundamentally essential to their physical interpretation.

Ordinary dried peas were used for the main part of the study. These were soaked in water and then germinated, and allowed to grow in moist sand, or on moist filter paper in a moist chamber in darkness. Hand transverse sections of the cotyledons were

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[1] Botanical Contributions from the Johns Hopkins University, No. 29.

[2] Rywosch, S., Über Stoffwanderung und Diffusionströme in Pflanzenorganen. Zeitschr. für Bot. 1: 571–591. 1909.

made daily, these being treated with iodine and examined with reference to the progress of starch removal. Other material was fixed in chrom-acetic acid, serially sectioned in paraffin, and stained with gentian violet followed by a rather strong staining with orange-G.

The cotyledons of the ripe seed are completely packed with starch, the digestion of which, during germination, begins in the peripheral cells on the convex side of each cotyledon. (Fig. 1, a.)[3] A short time later, digestion is to be observed in the peripheral cells of the flat face. The removal of the starch gradually works inward toward the vascular bundles. The enzymotic action at any one time seems to be confined to a layer two or three cells in thickness, the starch being almost completely removed from this layer before any marked amount of solution is to be observed in the adjoining cells lying nearer the center of the cotyledon. (Fig. 1, b and c). Finally the starch is removed from the entire cotyledon, except that usually a few groups of cells and a few isolated cells persist in retaining their starch without any apparent change (Fig 1, d). A few exceptional cases were observed, in which this progression of the enzymotic activity was not found, but in most cases it is very definite.

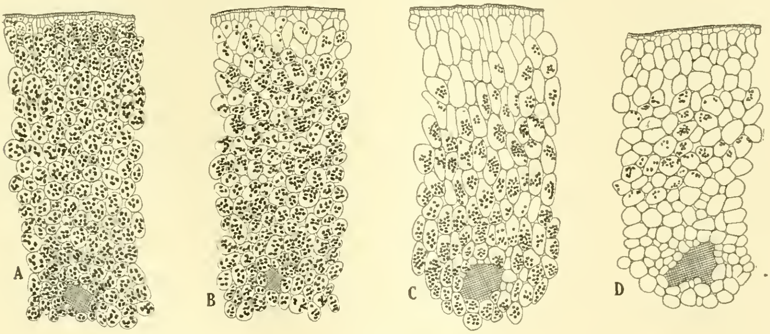

Fig. 1

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[3] Figures 1, 6, and 7 are made from camera lucida drawings reduced to a magnification of ×25.

This progressive solution of the starch was noticed by Sachs[4] in the cotyledons of the germinating bean. He believed that the starch which was dissolved, and which diffused into a neighboring cell, was there again deposited as starch.[5] While this doubtless occurs in other plant tissues, according to the work of Rywosch on *Vicia*, and to my own studies on both *Pisum* and *Vicia*, there is no evidence during germination for such reprecipitation.

Gris[6] states that the solution of the aleurone in the endosperm of *Ricinus* begins first at the periphery, and progresses inward toward the inner face, *i.e.*, that lying next to the cotyledons. He, however, offers no explanation, merely remarking that it is "une exception singulière" (p. 100). Van Tieghem[7] also studied the digestion of the aleurone of *Ricinus* seeds. He states that the progressive solution "s'explique par la marche même de l'eau d'imbibition" (p. 187).

Linz, in his work on the physiology of germination of maize[8] suggests that the similar phenomenon in the scutellum of maize is caused by the lowering of the activity of the diastase in the internal cells by the increase of osmotic pressure, due to the diffusion of the sugar solution from the peripheral cells. Rywosch points out the main objection to this theory, namely, that the osmotic pressure is higher in the peripheral cells, where the diastase is obviously most active, than in those lying nearer the center, for otherwise the diffusion stream would not be centripetal.

A consideration of the hypothesis of Van Tieghem suggests several possibilities. Is there an enzyme already formed in the ripe seed, or is it formed by the action of the water of imbibition on the living protoplasm? In the former case, in the enzyme dis-

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[4] Sachs, J., Physiologische Untersuchen über die Keimung der Schminkbohne. Sitzungsber. Wien. Akad., Math. Nat. Hist. Klasse, **37**: 57–119. 1859.

[5] Sachs, J., Handbuch der Experimental-Physiologie der Pflanzen, p. 395. 1865.

[6] Gris, A., Rechèrches anatomique et physiologique sur la germination. Ann. Sci. nat. Bot., V., **2**: 5–123, p. 100. 1864.

[7] Van Tieghem, P. Sur la digestion de l'albumen. Ann. Sci. nat. Bot. VI, **4**: 180–189. 1876.

[8] Linz, H., Beiträge zur Physiologie der Keimung des Mais. Jahrb. wiss. Bot. **29**: 267–319. 1896.

tributed throughout the cotyledon, or does it exist only in the peripheral layer or layers of cells? To answer these questions several experiments were performed.

Experiment 1. Dried peas were ground, and treated with concentrated glycerine. After standing for about an hour, the mixture was filtered. Some of the filtered extract was added to a thin starch paste, and kept at 50°C. The starch was soon changed to sugar, showing that active diastase had been extracted without any contact of the living protoplasm with water.

Experiment 2. Pea testas, removed from the dried seeds, were ground and extracted, both with glycerine and with water. When tested with starch paste, both the glycerine and the aqueous extracts showed diastatic activity, thus demonstrating the presence of diastase in the testa. It is of interest to note here that Wohllebe,[9] in his work on the enzyme content of the various parts of seeds, obtained no diastatic secretion from the testa of *Pisum sativum.*

Experiment 3. The peripheral layer of cells was removed from the cotyledons by means of a file. The filings were extracted with water, and the extract tested with starch paste. A diastase was present.

Experiment 4. Peas, from which the testas had been removed, were soaked in water for about five minutes, and the softened outer layer scraped off. An aqueous extract of this softened mass showed the presence of a diastase.

Experiment 5. Material from the interior of the cotyledon was obtained by breaking the cotyledons of dried peas, and drilling into the broken surface with a dental "burr." The powder so obtained was treated with water, and the diastatic action was obtained with the extract.

It is seen then, from these experiments, that an enzyme, or possibly a zymogen activated by water, is present throughout the cotyledon and in the testa. It is also clear that this enzyme is not formed by the action of the water of imbibition on the living protoplasm. Is it possible, however, that the water of imbibition

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[9] Wohllebe, H., Untersuchungen über die Ausscheidung von diastatischen und proteolytischen Enzymen bei Samen und Wurzeln. Diss. Leipzig, 1911.

does factor merely by wetting, and so starting the activity of the peripheral cells sooner than those of the interior?

Experiment 6. The cotyledons of dried peas were mutilated by filing in several ways:

(*a*) The peripheral layer of the entire convex side was removed, leaving only internal cells exposed on the convex face, and peripheral cells exposed on the flat face (fig. 2, the shaded portion denotes the part removed).

(*b*) A slab was filed from the convex side, leaving some peripheral and some internal cells exposed on the convex face, the flat face remaining normal (fig. 3).

Fig. 6

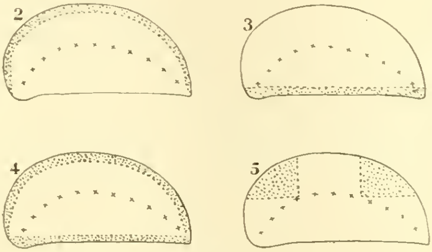

Fig. 2-5

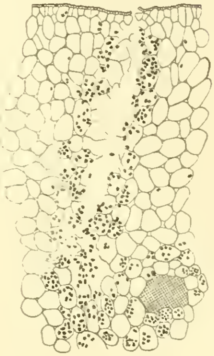

Fig. 7

(*c*) As *b*, but with the entire peripheral layer of the flat face also removed (fig. 4).

(*d*) Two deep notches were cut into the convex face, thus exposing some of the internal cells (fig. 5).

These dry mutilated cotyledons were then placed on wet filter paper in a moist chamber, and kept in darkness. Other seeds, mutilated in the same ways, were soaked in water before placing in the moist chamber. Unmutilated cotyledons were used as control. Rough examinations were made from time to time by means of hand sections stained with iodine, and material was also fixed in chrom-acetic acid, imbedded in paraffin, sectioned, and stained with gentian violet and orange-G. The results were the same whether the seeds were first soaked or not. The solution of the starch began in the naturally peripheral cells. In the internal cells which had been exposed by the mutilation, digestion did not begin at once, but only at about the same time that the cells in the same relative position in the control cotyledons began to show a solution of the starch (fig. 6). In other words, in all cells which have relatively the same position in the cotyledon, solution of the starch occurs at approximately the same time, irrespective of any mutilation of the surface layers. Mutilations causing the internal cells to lie at the surface do not at all hasten the solution of the starch in those cells. In such cases, the cells of the interior, exposed by the mutilation, surely become wetted as soon as the peripheral cells, yet the starch is dissolved first from those cells which are normally peripheral, and only in their proper turn from those normally internal. It seems improbable, therefore, that differences in the imbibed condition of the different cell layers can play any part in causing the difference in behavior of these layers in regard to starch digestion.

While examining the sections obtained from the mutilations of experiment 6, it was noticed that the starch in those cells which had been injured during the mutilation was not at all affected. This suggested that a mechanical injury, which might be supposed to bring about cell death, might prevent the solution of the contained starch, even though diastatic digestion progressed vigorously in immediately adjoining cells. To acquire more information on this point, dried peas were soaked in water until imbibition was complete, then the cotyledons were deeply punctured by means of a sterile needle. These peas were allowed to germinate in a moist chamber. Sections made from time to time showed that the solution of the starch proceeded in a quite normal manner except in those cells which had been injured by the needle (fig. 7). In these cells, the starch persisted in its original condition, even until the remainder of the cotyledon had been completely deprived of this substance. This lack of the solution of the starch can hardly be due to the mere killing of the cells, for in experiments 1 and 5 the cells were surely killed during the grinding, yet in these, the enzymotic activity began as soon as water was added.

There remains the possibility of a quantitative difference in the amount of enzyme present in the different parts of the cotyledon. To investigate this, five lots of material were prepared as follows: (1) the entire pea, ground; (2) the embryo, without the testa, ground; (3) the testa, ground; (4) peripheral cells of the cotyledon, filed from the convex face; (5) cells from the interior of the cotyledon, excavated with a dental "burr." Half a gram of each powder was treated with 10 cc. distilled water for an hour, and filtered. One gram of pea starch, thoroughly washed and dried in a desiccator, was dissolved, with boiling, in 160 cc. distilled water, 4 cc. of the filtered extract from each of the five lots were mixed with 16 cc. of the starch solution. A control was made by adding 4 cc. of distilled water to 16 cc. of the starch solution. The mixtures were then kept at 50°C. until all starch had disappeared.

The starch was entirely digested in these solutions in the following periods, approximately:[10]

1. Entire pea, nine hours.
2. Embryo, without testa, eight and one-half hours.
3. Testa, nine hours.
4. Peripheral cells of cotyledon, three hours.
5. Internal cells of cotyledon, nine hours.

At the end of nine hours the control showed no change.

This experiment shows clearly that there is a much greater enzymotic activity in the extract from the peripheral cells of the cotyledon than in any of the others. The difference may be due (1) to an actually greater amount of enzyme present in these cells, (2) to the presence of some inhibiting or retarding agent in the cells of the internal region, or (3) to the presence of an accelerating agent in the peripheral region.

Lack of time prevented the further experimental study of this interesting problem, but it is hoped that the points here brought out may be of use in ultimately gaining an insight into this somewhat peculiar sequence in cell activity.

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[10] Owing to the presence of a protein giving a greenish reaction with the iodine, the exact time required for the hydrolysis of the starch could not be made out.

NOTES ON THE PHYTOGEOGRAPHY OF THE ARIZONA DESERT

J. C. BLUMER

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In the winter of 1911 the writer made a trip, through the kindness of Mr. S. G. McWade, of the Cababi Mining Company, into the Cababi, Comobabi, and Quijotoa mountains and the surrounding country, including the Qui-i-to-woc hills. This region is situated from 75 to 100 miles west of Tucson, and lies in the heart of one of the most unique and remarkable floral empires of the earth, the Lower Sonoran region of southern Arizona. It is about these rocky desert ranges and immensely broad plains, or valleys, that some of the greatest extremes of heat and drought obtain that are known within the boundaries of our country. However, during February, the month in which the trip was made, the weather was cool, clear and windy. Three or four cloudy days culminated in a light rain on February 12, and in a succession of flurries of frozen rain on the 16th, resulting in a hoar frost the next morning, with the thermometer at 28°F. It is almost needless to state that none of the desert vegetation appeared to take the slightest harm from this moderate extreme. At the same time at Tucson a protracted rainy period and rather low temperatures prevailed, showing that climatic extremes may vary greatly between places of equal elevation and less than 100 miles apart. If this difference is typical it indicates that the gentle protracted rains of winter and also the copious summer showers center about the high mountains near Tucson and eastward, leaving a rapidly diminishing rainfall to the westward. On a side trip to the Qui-i-to-woc hills on the 16th even such a desert range as the Baboquivari was seen on the eastern horizon wrapped in a mantle of snow.

Chief among the constituents of the desert forest—for a forest it is, although more strictly known to phytogeographers as bush-land—is the palo verde, *Parkinsonia microphylla.* It is usually by far the most abundant of the low and bushy desert trees, dotting the surface as single individuals in orchard-like disposition, forming the real body of the forest. Its olive green appearance undergoes no perceptible change between winter and summer, for although it has its seasons of leafing and leaf-fall, regulated primarily by the seasons of rainfall, the leaves are so minute that a novice needs to handle a branch before he can convince himself of their presence or absence. Along the larger washes *Prosopis velutina, Acacia greggii,* and an occasional *Cercidium torreyanum* are present, while areas of *Olneya tesota*, the ironwood, also appear. This is the largest and handsomest tree of the desert, reaching occasionally a height of 25 or 30 feet and a trunk diameter of 12 inches, and, unlike the palo verde, producing a very hard and heavy wood. All these species,—aside from the arborescent cacti the only trees,—belong to the Leguminosae, representing each of its three subfamilies. The mining companies have large amounts of wood cut and hauled for their own use by the Indians at the extremely low cost of $1 to $1.50 per cord.

A striking feature of the landscape, overtopping the bush forest, is the giant cactus or sahuaro, *Carnegiea gigantea.* In the vicinity of Tucson it is of more localized distribution, seeking its most favorable situations on rocky hills and mountain sides. Here, in the midst of the desert, it raises its giant columns on every hand, plains and hills alike, except that it is usually scarce on the finer soils and the shadier sides of the hills. As elsewhere, it is especially strong on rocky southerly aspects, with dark-colored rock and soil, on the mountain sides, and on rough, eroded topography, and coarse, gravelly or rocky soils of the detrital plains.

Nearest of kin to the sahuaro, in this region, is the pitahaya or organ cactus, *Lemaireocereus thurberi.* The first specimens of this plant were seen on a rocky south slope in the Cababi hills. Later perhaps a dozen more were seen in similar habitats in the same hills, and it was reported to the writer on trustworthy authority from the south end of the Comobabi mountains and the Quijotoa range. In the latter it was found by the MacDougal expedition of 1907. It was not found by the writer in skirting the western foothills of the Baboquivaris nor in the Qui-i-to-woc hills. It is probable that these occurrences mark the northeastern limit of the species. Its altitudinal as well as its geographical limit of distribution thus falls considerably short of that of the sahuaro, while their habitat affinities are clearly indicated to be identical, *i. e.*, the first outlying specimens of the pitahaya are found in the optimum habitat of the sahuaro.

It may not be amiss to give a brief description of the first organ cactus encountered. It was branched at the base into 21 fluted, cylindrical stems or columns, 4 to 6 inches in diameter, which at first curved outward, then ascended vertically, the tallest to a height of 10 feet. Five stems examined were similar to those of the sahuaro, and had 18 and 19 ribs each, crowned with fascicles of slender spines numbering from 15 to 19 in each areole. The sahuaro has usually from 20 to 25 ribs and an equal number of spines in each fascicle. Another plant, from which specimens were collected, had 44 columns of all ages and sizes. These arose at or near the base, which was of the diameter of a large sahuaro, or else from primary branches. Sometimes branching takes place higher up, and in these cases it appears to be the result of mechanical or other injury to the parent stem. The tallest of these columns measured 12 feet, and was 7 inches in diameter.

The pitahaya possesses what at first sight appears to be a sickly yellow color, but this yellowish tint proves to be a natural character, distinguishing it from the clearer green of the sahuaro. The hot south side of the highest of the Cababi hills, at whose base a group of pitahayas were found, is covered with jet black rock and brown soil. Here two cacti were found very strongly represented, *Opuntia bigelovii* and a large *Echinocereus* that does not occur about Tucson but is common in this region. Its many cylinders, some of them reaching a height of 18 inches or 2 feet, are covered with very long and numerous spines. The plant is marked by a strong yellow color, and is so numerous on this slope as to lend a dominant character to the vegetal covering. Similarly, the Bigelow cholla, were it not for the fact that they rarely grow together, could be readily distinguished from its sister species *Opuntia fulgida* by its yellowish tint. A causal relation is thus suggested by these three species between the hot and dark character of their habitat and their yellow color.

The desert shrub possessing the largest leaf is the compositous, monoecious half-shrub *Franseria dumosa*, which is found only on the larger washes and rarely on the well sheltered north side of cliffs. Aside from the cacti and an occasional *Ephedra* and *Koeberlinia*, which are leafless, the plant having the smallest leaves is *Parkinsonia microphylla:* it is the most abundant of the trees of the real desert and enjoys the most general distribution. The contrast between these forms is readily apparent.

The bulk of the winter annual vegetation, just coming into bloom at that time, belonged to eight species of Cruciferae and five species of Borraginaceae. These are well known to be predominantly circumpolar families, *i. e.*, they are adapted to low temperatures both in season and in geographic distribution.

The Cababi hills and the extremely rocky foothills of the Comobabi mountains bear a large number and variety of shrubs, cacti and smaller perennials. The flora of such rocky hillsides is always richer in species than that of the deeper soil of the alluvial and rockless detrital plains adjacent. The winter annuals, always more abundant on northern than on southern slopes, in the present perhaps somewhat unfavorable season are confined to the shadiest and moistest portions of strictly northern slopes. In strong contrast to the dark rock and soil and the grassless vegetation, stands out the gregarious and formidably armed Bigelow cholla, rendering many hillsides almost white at a distance and scarcely traversable when at hand.

The country on the top of the southern part of the Comobabi mountains is by no means as forbidding as is suggested by the foothills. The geologic formation is older, traversed by dykes in a northwest-southeast direction. There is much undulating, grassy country, the grasses and herbs being mostly perennials, but with a considerable number of common annuals amongst them. The country is dotted with shrubs, the most prevalent being *Acacia greggii*. *Prosopis*, *Condalia lycioides*, and *Lycium fremontii* are present occasionally. A few scattering giant cacti reach the south sides of the highest summits, and *Fouquieria splendens* and *Jatropha* *cardiophylla* are common about the dykes and rocky places. In such habitats are also found *Eriogonum wrightii*, *Coleosanthus coulteri*, *Tragia* and *Krameria*. Most conspicuous of all, because dark evergreen, is a dotting of *Yucca brevifolia*. Two platopuntias, *Opuntia discata* and *O. chlorotica*, and a species of cylindropuntia are found. A short-spined relative of *Echinocereus fendleri* inhabits the dykes, in which habitat is also found, as is usually the case, the rainbow cactus, *Echinocereus dasyacanthus*. Even the sunset cactus, *Mamillaria grahami*, is still present, and becomes decidedly abundant on the desert hills below. Three species of *Echinocactus* are found growing in close proximity, one of these being *E. emoryi*, a species of striking beauty which is also found occasionally at lower elevations. *Calliandra eriophylla* now becomes an abundant dwarf shrub on rocky areas of sunny slopes just as at the same altitudes elsewhere. From this characterization of the physiognomy and partial census of the species we may know that we have here an elevation of 4000 to 4500 feet.

The steeper slopes, especially on north aspects, are taken by an often dense growth of *Simmondsia californica*, just as they would be taken by evergreen oaks if the mountains were higher. This dioecious evergreen shrub with dark and coriaceous foliage and somewhat acorn-like fruit, takes the place of the chaparral oaks in exactly similar though lower habitats and justifies the local name "desert oak" in more ways than one. The fruit of the jojobe, which is the Mexican name for this shrub, and that of the sahuaro form two staples articles of food for the numerous Papago Indians inhabiting this region. The desert oak is the most abundant evergreen shrub of the strictly woody class that is found in the desert mountains.

The summits of the middle Quijotoa mountains present a different appearance from the Comobabi range. The geologic formation is an old one, and the rock a granite, giving rise to the Quijotoa gold placers at the eastern base of the mountains. The range is narrow and the peaks are sharp, probably not exceeding 4500 feet in elevation. To the north the crest of the range is similar, but less in altitude, being flanked on the west by the Sierra Blanca. The southern part of the range, in which its axis extends due north and south, is but little higher, and of darker color, presenting flat summits and sheer precipices, evidently remnants of later basaltic outflows. The hazy desert, when viewed from this range, stretches boundless in every direction, with countless low mountain ranges everwhere. Some have erosional outlines, others show remnants of peneplains or volcanic flows.

Although the date was the 15th of February, the summit that formed the viewpoint was crowned with a golden glow of California poppies, and with the showy *Lupinus leptophyllus.* The dominant shrub is *Yucca brevifolia,* with *Simmondsia californica* second in number. *Fouquieria splendens* and *Lycium berlandieri* are present, while *Calliandra eriophylla, Encelia frutescens, Eriogonum wrightii, Euphorbia melanadenia, Lotus rigidus* and species of *Sphaeralcea* and *Artemisia* form the mass of the smaller perennials. A considerable growth of grass is present, in which are to be found *Heteropogon contortus* and species of *Bouteloua* and *Aristida.* A smooth, scarlet-flowered pentstemon of great beauty, *Pentstemon centranthifolius,* was just coming into bloom, as well as *Anemone sphaenophylla* and *Brodiaea capitata.* Among the cacti *Opuntia chlorotica* is present, and the yellow *Echinocereus* of the Cababi hills, first seen in the Comobabis, is found to be common. On the southeast slope are to be seen *Carnegiea gigantea* and *Echinocactus emoryi,* and a few cylindropuntias are still sparingly represented, including *Opuntia bigelovii.* A few plants of *Encelia farinosa* and *Jatropha cardiophylla* were also noted. Being desert species, the last five or six named ascend the mountains only on the sides facing the equator, as may be expected. A number of annuals are in evidence, among them *Pectocarya, Phacelia distans, Thysanocarpus curvipes, Amsinckia tessellata, Astragalus nuttallianus,* and *Rafinesquia (Nemoseris) neo-mexicana.* That the factor of exposure (not aspect) is operative in the desert as well as on boreal mountain tops is shown by the fact that *Parkinsonia microphylla* is on this summit reduced to a shrub little more than 2 feet in height. The same is true of this species on some of the Comobabi summits.

To the east of the Quijotoa mountains lies the valley of the same name. On crossing it in a westward direction, we find first the same forest of giant cactus and palo verde as noted above, with a sprinkling of ironwood, and *Franseria* as an abundant ground cover. *Opuntia fulgida*, *Echinocereus fendleri* and a variety of flat-jointed prickly pears are the principal cacti. The California poppy in places enlivens with yellow the sprouting green of the annuals. Finally a belt of the creosote bush, *Covillea tridentata*, succeeds, and on reaching the playas and Indian farms we get on the fine sedimentary soils *Bigelovia hartwegii*, *Atriplex canescens*, and *Baccharis sarothroides*. The belt of mesquite in the lowest portion is, as usual, sharply differentiated from the *Covillea* belts of the gentle slopes adjacent. In ascending westward, the latter species at first holds complete sway, then again gradually gives way to *Parkinsonia* and *Franseria*, which latter in turn is displaced more or less completely by *Encelia* before the mountains are reached. A large number of other species begin to appear in proportion as the soil becomes more rocky, this number reaching its maximum on the north slopes of the sheltered cañon troughs in the mountains, and in the troughs themselves.

BOOKS AND CURRENT LITERATURE

Distribution and Origin of Life in America.—This great work[1] by Dr. Scharff will be welcomed by all students of distribution, whether the author's conclusions, which lead far from beaten paths, are accepted or not. It is a veritable mine of wealth in its extraordinary accumulation of data from all available sources, and its value is enhanced by the large number of recent observations drawn from living writers and the author's own extended knowledge in his special field.

Beginning with northern North America, the author takes the ground that we possess no direct evidence for the general belief that the climate of Greenland was much colder during the Glacial Epoch than it is now, and that no special reason can be adduced why the present flora of Greenland should not have survived the Ice Age. The well-known features of distribution in the White Mountains, Labrador and the region to the westward, though giving abundant evidence of extensive migration, calling for the assumption that land connections with Europe and Asia existed long before the Glacial Epoch, are interpreted on the theory of survival over discontinuous areas rather than as evidences of a general movement to higher latitudes and altitudes during the retreat of the ice. In fact the author distinctly states his belief that the climate of boreal North America during the Ice Age, though much more humid than at present, so that it led to extensive glaciation on all higher mountain ranges, was not arctic but temperate, and that in many parts within the so-called glaciated area there existed islands where life was abundant and survived to the present day. The author holds that long before the commencement of the Glacial Epoch the animals and plants from Labrador found their way southward to the White Mountains. It may well be that such far-reaching conclusions will not find general acceptance, but at all events they call for a thoughtful hearing.

A large amount of space is necessarily given to the several great biological regions which succeed each other on the long way from Alaska to Patagonia. Evidence is brought forward which seems to point

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[1] Scharff, R. F. Distribution and Origin of Life in America. Pp. 497, figs. 21. New York, The Macmillan Company. 1912. ($3.00.)

plainly to the existence in Alaska during the Ice Age of conditions more favorable for both plant and animal life than are those of the present time, and additional data are given pointing not only to the existence of a geologically recent land bridge between Asia and America by way of Bering Strait but also more definitely assigning its date: "during Pliocene times until the commencement, or perhaps until the end, of the early part of the Pleistocene period." According to the author "there is no indication of any wholesale destruction of the fauna during the Glacial Epoch, followed by a recent introduction from the south."

In the Rocky Mountain region and in the arid regions of southwestern North America occur, as is well known, various species of plants which are not met with in southern Mexico, Central America and the northern Andes, but which reappear in the extreme south of South America. Moreover, as early as in mid-Cretaceous times 75 per cent of the known plants of Argentina were characteristic types of the Dakota group flora of North America, which must be taken to indicate community of origin. From these and numerous other data the conclusion is reached that a direct land bridge between western North America and Chile probably existed in Cretaceous and early Tertiary times, and it even seems likely that various species of plants of those remote times have persisted to the present day, with the discontinuous distribution already indicated.

In like manner the steadily accumulating evidence derived from discontinuous distribution gives support to the assumption that, far more than leading geologists have admitted, the continents were connected by land bridges by which interchanges of plants and animals were effected as early as Tertiary times and even earlier. Such bridges are believed to have connected Chile and Patagonia with Mexico and California, the West Indies and areas both to southward and northward with the Mediterranean region, South America with Africa, southwestern North America with eastern Asia, and still other connections are traced with varying degrees of probability, approximating to certainty in some cases, as for instance the early continuity of land between New Zealand, South America and South Africa.

Without essaying the task of following the author further in his remarkable marshalling and interpretation of facts similar to those already noted, it may be said that his work, however modestly and in parts tentatively offered, is nothing less, as stated in its concluding words, than an attempt "to show how the gradual evolution of our continents and the former changes of land and water can be demonstrated by a study of the geographical distribution of living animals and plants." Geology (not to consider at this point other sciences) thus becomes debtor to the dead work of scores of botanists and zoölogists through whose labors for decades past the data in question have been accumulated, and much more to this one of their number whose gift of interpretation now presents to us a broader and clearer vision of world history. —V. M. S.

Practical Botany.—The mind trained by years of experience as a teacher and the practiced pen of Mr. J. Y. Bergen have given us, with the assistance of Professor Caldwell of the School of Education in the University of Chicago, still another school botany, called Practical Botany.[1] The preface states "There are already so many books embodying elementary courses in botany that whoever offers another should give reasons for so doing. As here set forth, the study of plants is related to everyday life more closely than is usually done. Those aspects of plant life are presented which have the largest significance to the public in general, and which are of interest and educative value to beginning students." The attempt is remarkably successful—in the book: but one cannot help wondering how successful the course may be in a city school from which park and country are remote and in which the teachers themselves are still more removed from nature. The teaching of the natural science by *un*naturalists is made less injurious by such excellent books as this: but parents will rejoice when their children come into the hands of teachers of such sympathetic knowledge of their subject as the writers of this book.—G. J. P.

Cereal Rusts.—Two papers by Pritchard[2] are a very material contribution to our knowledge of cereal rusts. This work on rust-infected grain seeds is really a step in the right direction toward the solution of the problem which led Eriksson to advance the mycoplasm hypothesis. No matter what may be our personal conviction as to the validity and adequacy of this hypothesis the fact remains that it has been a potent factor in stimulating valuable research on cereal rusts during the fifteen years in which it has been extant. It might be indicated in this connec-

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[1] Bergen, J. Y. and Caldwell, O. W., Practical Botany. Pp. 545, illustrated. Boston: Ginn and Company, 1911. ($1.30.)

[2] Pritchard, F. J., A preliminary report on the yearly origin and dissemination of *Puccinia graminis*. Bot. Gaz. **52**: 169–192, pl. 1. 1911. The wintering of *Puccinia graminis tritici* E. & H. Phytopathology **1**: 150–154, pl. 1, fig. 1. 1911.

tion that in spite of the several critical researches of Ward and the more recent ones of Zach and Beauverie, Eriksson still appears in defense of his hypothesis. Pritchard finds that rust-infected wheat grains contain living mycelium within the tissues of the pericarp adjacent to rust sori. The mycelium resumes its activity with the growth of the seedling, in case such infected grains are planted. The fungus penetrates the tissues of the young plant, growing also in the spaces between the leaf sheaths. The formation of new uredo sori from this mycelium has not been observed. When rigorous measures were used to exclude the possibility of external infection, rust-free plants were obtained on sowing rust-infected seed. Wheat sown at various dates remained nearly free from rust until it began to head, in spite of repeated attempts at inoculation. It is plainly evident that the fungus lives over winter in certain wheat grains and that this is at least one very probable source of infection. Whether after infection of the embryo there might not be a time at which the mycelium becomes virulent, namely, when it spreads to form pustules as is assumed in Eriksson's mycoplasm hypothesis is at least a very interesting possibility.—Frederick A. Wolf.

NOTES AND COMMENT

In laboratory experiments with water-cultures of higher plants it is usually expedient first to germinate the seeds to be used, and this demands the use of some medium in which germination will readily take place and from which the young seedlings may easily be removed with the least chance of injury. White pine sawdust, chopped sphagnum moss and quartz sand are commonly used for this germinating medium, but the first is becoming practically unobtainable, the particles of the other two materials cling tenaciously to the root surfaces and the process of removing the plantlets from the same mass is commonly accompanied by more or less injury. It was suggested to the writer that granulated cork might be suitable for this purpose, and, accordingly, this material was given a rather thorough test in connection with other experimental work which was carried out in the spring of 1911, at the Laboratory of Plant Physiology of the Johns Hopkins University. While the material here brought forward may well have been used by others, no note to this effect has been met with in the literature, and the apparently general utility of this method makes it seem advisable to publish the present observations. The granulated cork used was that which arrives in the American market as packing for Malaga grapes. This may be procured at a negligible cost from fruit dealers. The unused material may of course be obtained from dealers in cork. The cork was first sorted to remove grapes or other foreign bodies, and was then thoroughly washed in water. On removal from the washing vessel the cork was pressed between the hands to remove excess of water, and was then rather firmly packed in ordinary porous flower pots of the 6-inch or 8-inch size. The best germination was obtained when the seeds were planted nearly or quite twice as deep as the same form would be planted in sand. The pots stood, during germination, in water to a depth of about two centimeters, the level of the latter being kept approximately constant from day to day. It is well to let this level be automatically maintained by means of the ordinary Marriotte flask. The pots may be watered from above with practically no danger of raising the moisture content of the cork above the optimum; any excess of water rapidly drains away. Germination seemed to be somewhat better when the pots were left open above, rather than covered with glass or other plates; when left open the superficial layers of the cork become air dry and offer but little opportunity for the growth of fungi on the surface. Seeds of the following plants were tested: maize, wheat, oats, Canary grass (*Phalaris*), pea, lupine, Windsor bean (*Vicia faba*), kidney bean (*Dolichos*), garden nasturtium (*Tropaeolum*), mustard, rape, castor bean, squash, cucumber, buckwheat, morning glory, tomato and sunflower. All of them gave excellent results. Several of the larger legumes germinated much better in cork than in sand or moss, doubtless because of the smaller amount of water held by the cork. When the cork is first used it imparts to the water a dark color, but the soluble material thus made evident has no apparent effect upon the seedlings.—W. E. MANEVAL.

Prof. Aven Nelson, of the University of Wyoming, has just prepared a Spring Flora of the Intermountain States (Ginn and Company), a small volume covering a portion of the entire flora of its area for a portion of the year. The book will find use in the secondary and high schools of Wyoming, Colorado, Montana, Idaho, Utah, and Oregon. The fact that there is demand for such a book speaks well for the progress of botanical interest in the public schools of a not thickly populated group of states. The "keen and growing interest in the plants of the west," to which Professor Nelson alludes, is well worthy of being fostered, especially among the boys and girls of the region, from whom a large share of the botanists of the next generation will doubtless be recruited. This interest is also being manifested in the rapidity with which the western states are becoming provided with floras, which will at once be of great service to botanists themselves and a great stimulus to the rising generation to become interested in the classification of plants and, through it, in other departments of botany as well. California has been provided for a number of years with floras of its several diversified portions. Western Texas, Nebraska, Washington, Colorado, Wyoming, Montana, Minnesota, and Iowa also possess reasonably complete floras, while Kansas and Oklahoma have provisional lists of their plants, not to mention floristic works which cover portions of other states. A flora of New Mexico which has been elaborated by Prof. E. O. Wooton, formerly of the New Mexico Agricultural College, will shortly be published as a Contribution from the National Herbarium, and a flora of Arizona is now in preparation by Prof. J. J. Thornber, of the University of Arizona. A similar review of works relating to the floras of eastern states will reveal the fact that they bid fair to fall behind the western states in this activity. Particularly is it true, although with notable exceptions, that the west is better provided than is the east with works which not only list the flora but give some picture of the natural vegetation, together with precise observational data as to the habitats and limits of distribution of the various species.

A new elementary school book has been prepared by Frank Owen Payne, entitled Manual of Experimental Botany (American Book Company). The brief volume brings the student into contact with the commonest facts of plant physiology by use of the experimental method, and by the same method also touches upon the structure of the stem, leaf, and flower, modes of pollination, the nature of some of the commonest cryptogamic plants, and other matters which it is not usually considered possible to handle by the experimental method in teaching. Some preliminary chemical experiments are designed to obviate what must be one of the practical difficulties of the book. There are the usual touches of teleology here and there, but on the whole the book is a very commendable departure.

THE ECOLOGICAL SUCCESSION OF MOSSES, AS ILLUSTRATED UPON ISLE ROYALE, LAKE SUPERIOR

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Carmel, California

During the course of ecological study upon Isle Royale, Lake Superior, the importance of the mosses in the various successions leading up to the establishment of the final forest vegetation was strongly impressed upon me. The general results of the work are soon to be published elsewhere, but it may serve a useful purpose to summarize in a separate paper the observations relating particularly to the mosses. At the commencement of the investigation I was making my first acquaintance with most of the species, and the results are therefore not as complete as they would have been had the work been done by an expert in the group. The purpose of this paper is simply to point out the important part which the mosses play in certain plant successions, and to suggest some of the possibilities of an undeveloped field of study. A list of the species collected upon the island, about ninety in number, is soon to appear in the Bryologist.

Isle Royale is situated in the northwestern part of Lake Superior, parallel to the Canadian shore and about 25 km. distant from the nearest point of the mainland. It is a large island, being 70 km. long and 13 km. wide at the widest part. The topography is striking. A series of straight even-topped ridges extends from end to end, steep-sided on the northwest, sloping gently southeastward. Between these are long narrow parallel valleys, continued at the ends of the island as fiord-like bays bounded by rocky points, which are the extremities of the ridges.

Vegetationally the island belongs within the Northeastern Conifer Forest Region, although its proximity to the southern limit of this territory is suggested by a small area of sugar maples

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at the southwestern end—an outpost of the Eastern Deciduous Forest. The upland forest, which covers the island completely with the exception of narrow strips along the exposed shores and the bog areas in the valleys, is composed mainly of three trees, in order of abundance: Balsam Fir (*Abies balsamea*), Paper Birch (*Betula alba* var. *papyrifera*), and White Spruce (*Picea canadensis*). In the general paper mentioned above I have shown that this combination is the climax forest of Isle Royale, and probably of most or all of the Northeastern Conifer Region.

The plant successions leading up to the establishment of the climax forest are conveniently classified in two groups: the Xerarch Successions, having their origin in xerophytic habitats; and the Hydrarch Successions, originating in hydrophytic habitats.

Under the first head there are two, the Rock Shore Succession and the Beach Succession, the latter not extensively developed upon Isle Royale. The course of the Rock Shore Succession is briefly as follows. The pioneers upon the rock shores obtain their first foothold in three sorts of situations, thus initiating three separate lines of advance which may be conveniently termed "Subsuccessions." In the Rock Surface Subsuccession a crustose lichen stage is followed successively by foliose and fruticose lichen stages, large cladonias being dominant in the last. The Crevice Subsuccession is initiated by crevice herbs and these are followed by trailing shrubs, and even trees frequently appear. The Rock Pool Subsuccession has its origin in water-filled depressions, and advances through the building of a mat after the manner of the Bog Succession. These separate lines unite in the formation of the Heath Mat, in which the elements of the rock surface and pool vegetation are bound together by the trailing shrubs from the crevices. A xerophytic forest stage, characterized by Jack Pine (*Pinus Banksiana*) and Black Spruce (*Picea mariana*), but seldom found pure, may here intervene, or the climax forest may follow directly the establishment of the heath mat.

The Hydrarch Successions are also two in number, and of these the Bog Succession is the more important. In the Delta Swamp

Succession mosses take little part, and it will therefore be eliminated from the present discussion. In the course of the Bog Succession lake basins become filled through the centripetal encroachment of vegetation. The stages upon Isle Royale are as follows: aquatics; sedge mat; shrub or shrub-sphagnum; bog forest; climax forest.

A "secondary succession" should be mentioned, which follows the burning of the forest and leads back to the climax state. In this mosses play a subordinate part.

I. THE ROCK SHORE SUCCESSION

The rock shores of Isle Royale may be classified in various ways: according to slope, degree of exposure to waves and wind, and material. There are vertical cliffs, particularly characteristic of the northwest coast of the island, and gently sloping shores, corresponding to the dip of the strata, found mainly upon the southeast coast. Along the land-bound harbors are shores that are thoroughly protected from wind and waves, with forest to the water's edge; while along the exposed southeast coast there is a broad belt of bare rock supporting a sparse vegetation or none at all. The material of which the shore is composed is important in its physical rather than in its chemical character. The manner and degree of weathering, with resulting rough or smooth surfaces, abundance or paucity of crevices, are the variable conditions that affect plant life. Upon all these types of coasts the course of the succession is in general the same, but we find that the stages are most fully represented and most plainly marked upon the gently sloping shores about midway in the scale of exposure. In fully sheltered situations the preliminary stages of the succession have all been passed through and the climax forest extends to the water's edge, while upon the most severely exposed shores some of the intermediate stages are apt to be missing, "pinched out" by the advance of the forest against the impregnable barrier of waves and ice.

At a variable height above the lake level, according to degree of exposure, the three subsuccessions have their beginnings.

Upon the bare rock surfaces grow crustose lichens, together with numerous tufts of *Grimmia ovata* Web. & Mohr (fig. 1). This species is found as near to the water as any of the lichens, and frequently lower, and clings as closely to the rock. It is the most abundant moss at the lower edge of the crustose lichen zone, but two other species are usually present. *Orthotrichum anomalum* Hedw., which is commonest a little higher up, and *Hedwigia albi-*

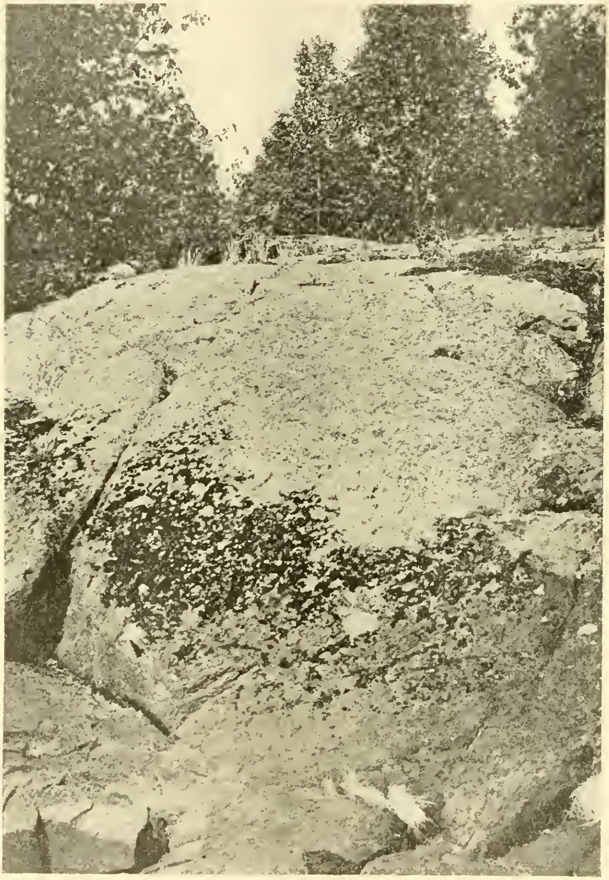

Fig. 1 Bare rock shore of Rock Harbor. A belt of *Grimmia ovata* (black), with foliose lichen zone above it.

cans (Web.) Lindb. Above this zone is another in which the foliose lichens are the most conspicuous plants. *Grimmia* and *Orthotrichum* have now lost their dominance, being eliminated in the competition with the larger lichens and *Hedwigia*, which is here the commonest moss. In the third lichen zone, dominated by fruticose forms, especially the large cladonias, mosses are infrequent, being unable to compete with the comparatively tall and wide spreading lichens in the contest for space and light. *Rhacomitrium canescens* (Timm.) Brid. var. *ericoides* (Web.) Schimp. sometimes accompanies the cladonias, making the mat more coherent than where it is absent. *Hedwigia* persists to some extent, and the other two pioneer species occur in areas of incomplete invasion.

In the Crevice Subsuccession mosses are of little importance, *Polytrichum juniperinum* Willd. and *P. piliferum* Schreb. being the commonest species occurring as crevice plants. In the late stages of the subsuccession *Thuidium abietinum* (L.) B. & S. often appears. In sheltered crevices, particularly upon the steep northwestward facing cliffs, occurs a rather numerous group of mosses, of which the commonest is *Swartzia montana* (Lamk.) Lindb. Others are *Bartramia pomiformis* (L.) Hedw., *Bryum intermedium*, *Encalypta ciliata* (Hedw.) Hoff., *E. procera* Bruch., *Hylocomium triquetrum* (L.) B. & S., *Neckera pennata* (L.) Hedw., *Pogonatum alpinum* (L.) Roehl., *Polytrichum commune* L., *Tortula ruralis* (L.) Ehrh. Because of the verticality of the surfaces, such habitats remain much the same for a long time, and one frequently finds small cliffs in the fully developed climax forest bearing a moss flora almost identical to that listed above.

In the Rock Pool Subsuccession mosses are frequently absent, but in certain pools they are the exclusive mat formers. Several depressions were seen in which were growing luxuriant masses of *Climacium americanum* Brid. In one locality a mat of *Polytrichum commune* and *Aulacomnium palustre* (L.) Schwaegr., one-third of a meter thick, bound together with roots and rhizomes of various plants, was growing out into a rock pool. The area under the control of the moss was about one square meter—one-fifth of the total. Upon the surface of the mat grew cladonias and various shore plants. Another depression, probably having once contained a pool, was found completely filled with a mat of *Aulacomnium* and *Polytrichum strictum* Banks, bound together in the same manner as the last. Other species found inhabiting the margins of rock pools were *Amblystegium Kochii* B. & S., *A. fluviatile* (Sw.) B. & S., and *Campylium stellatum* (Schreb.) Bryhn. In certain wet depressions and particularly along crevices containing intermittent small streams *Bryum Muhlenbeckii* was frequent.

In the formation of the heath mat (which must not be understood to be often continuous over extensive areas) the three subsuccessions unite. Many of the early arrivals among the mosses still persist, and numerous others, including those peculiarly characteristic of the climax forest, make their appearance. Most important at this stage are *Thuidium abietinum* and *Calliergon Schreberi* (Willd.) Grout, which are frequently abundant in a stunted condition among the tangles of *Juniperus horizontalis, J. communis* var. *depressa* and *Arctostaphylos Uva-ursi,* which form so important a part of the heath mat. Besides contributing to the supply of humus the mosses now come to aid in the conservation of soil moisture. Upon areas where crevices in the underlying rock are rare the large cladonias (*C. rangiferina, C. sylvatica, C. alpestris*) form extensive dense growths during the late stages of the Rock Surface Subsuccession, which frequently remain intact until entirely surrounded by the climax forest. *Calliergon Schreberi* is apparently the only species that is able to supersede the cladonias in such places. The young plants germinate among the branches of the lichen clumps and gradually spread over their surfaces, cutting off light and air and thus bringing about their death. An excellent example of this is shown in figure 2. If the *cladonia* areas remain uninvaded until the forest surrounds them they are termed "rock openings" and become very pleasing features of the woodland scenery. In addition to *Calliergon* and *Thuidium,* the following forest species commonly make their first appearance with the heath mat: *Dicranum undulatum* Ehrh., *Hylocomium proliferum* (L.) Lindb., *Hypnum crista-castrensis* L., *Hylocomium triquetrum,* which has already been mentioned, is sometimes of considerable importance. It is thus seen that the characteristic forest mosses become established notably in advance of the forest itself.

In cases where the xerophytic forest stage, characterized by *Pinus Banksiana* and *Picea mariana,* intervenes, the undergrowth is practically a continuation of the heath mat, with the three forest mosses, *Calliergon Schreberi, Hylocomium proliferum,* and *Hypnum crista-castrensis,* gradually attaining dominance. In early stages it is common to find a ground cover composed largely of cladonias, with practically no humus. In a slightly more advanced condition *Calliergon* is gaining the upper hand and the climax trees are coming in. Later still *Hylocomium* and *Hypnum* are found disputing the dominance of *Calliergon,* and the climax trees increasing at the expense of the jack pine and the black spruce. When the climax state is attained the latter trees have disappeared, balsam fir, paper birch, and white spruce are in control, and the undergrowth is composed largely of *Calliergon, Hylocomium,* and *Hypnum* in about equal proportions.

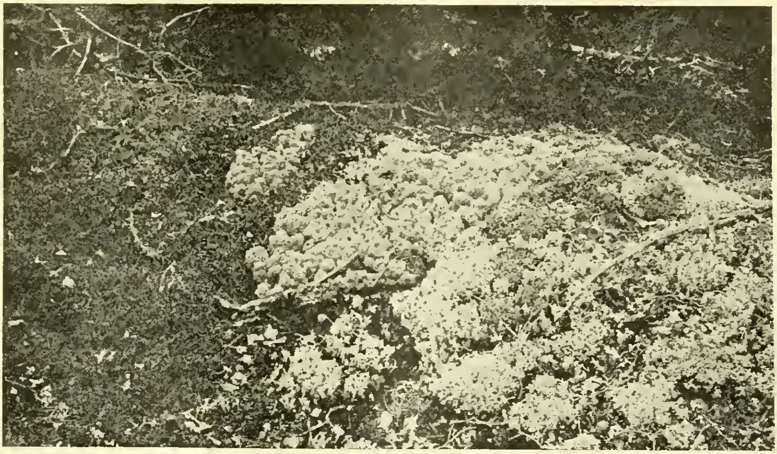

Fig. 2 Xerophytic forest near Amygdaloid Harbor. Cladonias (*Cladonia alpestris, C. sylvatico, C, rungiferina*) at right, invaded by *Calliergon Schreberi* (dark mass at left).

The increasing mesophytism from the heath mat stage onward is due, more than to any other factor, to the increasing abundance of the three mosses just named, with its results, continual additions to the humus accumulations, and effective conservation of moisture. Before they enter, the amount of humus upon the rock surfaces is almost negligible; in the climax forest the depth is sometimes a meter, and it is composed largely of moss remains, together with rotten wood and tree waste of various kinds.

In discussion of the place of mosses in the Rock Shore Succession a stage must be recognized which in an account of the succession in general would more naturally be included with the climax forest. In certain parts of the forest, particularly upon the slopes of the ridges, boulders and small cliffs, remaining from shore or talus conditions, are common. These are usually covered with mosses, including a large number of species, together with a few liverworts, lichens, and higher plants. That this is an intermediate stage in the succession, although within the climax forest, is shown by the tendency of the climax mosses, *Calliergon Schreberi*, *Hylocomium proliferum*, and *Hypnum crista-castrensis* to extend their dominance at the expense of the less mesophytic species. Certain of the rock surfaces, formerly bare, are already covered with a thick carpet of the climax species, and it is evident that upon the disintegration of the boulders and cliffs this carpet will extend itself over all. The composition of the moss population of habitats such as these is of interest. The following list, made up from several localities, includes three groups: (1) climax mosses; (2) relict species remaining from earlier stages of the Rock Shore Succession; (3) forms that are specially characteristic of this habitat, including some found in no other.

(1)

Calliergon Schreberi (Willd.) Grout.
Hylocomium proliferum (L.) Lindb.
Hylocomium triquetrum (L.) B. & S.
Hypnum crista-castrensis L.

(2)

Hedwigia albicans (Web.) Lindb.
Orthotrichum anomalum Hedw.
Swartzia montana (Lamk.) Lindb.
Thuidium abietinum (L.) B. & S.

(3)

Bartramia pomiformis (L.) Hedw.
Brachythecium oxycladon (Brid.) J. & S.?
Brachythecium velutinum (L.) B. & S.?
Campylium chrysophyllum (Brid.) Bryhn.
Cynodontium polycarpum (Ehrh.) Schimp var. *strumiferum* Schimp.
Drepanocladus uncinatus (Hedw.) Warnst.
Eurhynchium strigosum (Hoff.) B. & S.
Leucodon sciuroides (L.) Schwaegr.
Neckera pennata (L.) Hedw.
Plagiothecium denticulatum (L.) B. & S.
Pogonatum alpinum (L.) Roehl.
Polytrichum commune L.
Pterygynandrum filiforme (Timm.) Hedw.
Thuidium delicatulum (L.) Mitt.

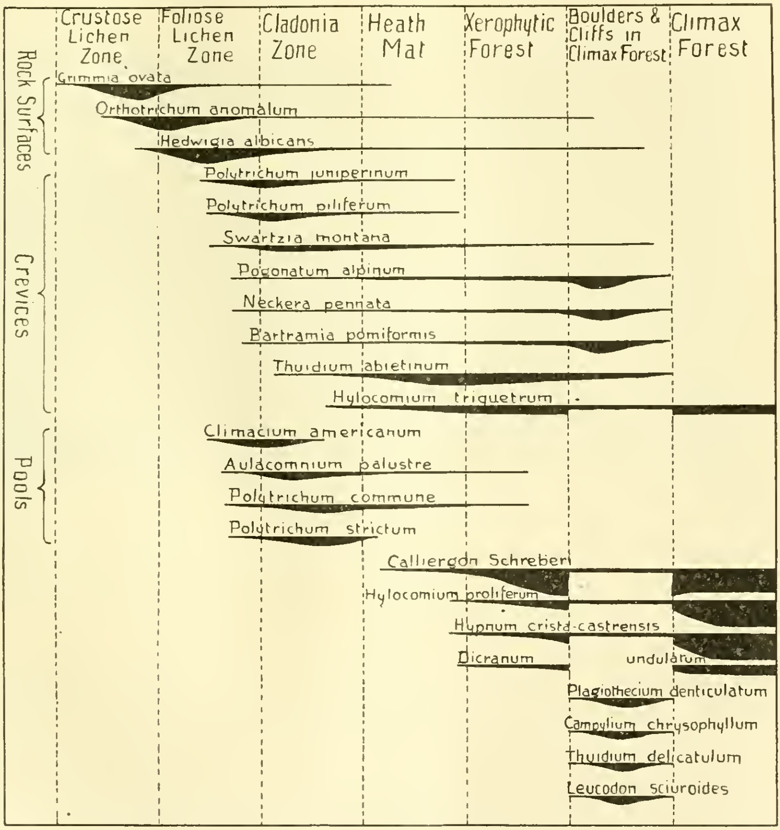

Fig. 3

Figure 3 shows the successional range of twenty-three important mosses of the Rock Shore Succession.

II. THE BOG SUCCESSION

In the course of the Bog Succession mosses first appear upon the sedge mat. Here they are of little importance, *Scorpidium scorpioides* (L.) Limpr. being the only one occurring commonly with the sedges. With the invasion of the sedge mat by the various species of *Sphagnum* a new stage is inaugurated in which the moss element is immensely predominant. Sphagnum does not appear abundantly in all of the Isle Royale bogs, and its abundance or practical absence in a given locality determines which of two diverging lines the succession in that locality will follow. If sphagnum is abundant, the principal bog shrubs that accompany it will be *Chamaedaphne* and *Ledum*, and the bog trees that follow the shrubs, tamarack and black spruce. If sphagnum is practically absent, the shrubs will be *Chamaedaphne* and *Alnus incana*, and the bog tree, tamarack, with or without arbor vitae. The causes of this divergence were not determined with entire satisfaction. One factor was observed however that undoubtedly plays a part: the composition of the sedge mat. In those bogs where sphagnum is abundant the dominant sedge was commonly found to be *Carex limosa*, a soft low growing species, producing no shade to speak of and offering little resistance to the spread of the moss. In bogs practically without sphagnum the sedge is *Carex filiformis*, growing in tall dense closely placed stools, which shade the ground between them and offer effective resistance to the horizontal spread of the sphagnum masses. The presence of *Ledum* and black spruce depends upon the previous occupation of the ground by sphagnum.

The contest between the sphagnum and the plants which precede and follow it is an interesting one. The sedges, especially *Carex limosa*, after having been practically buried by the moss, succeed for a time in holding their own by upward elongation, keeping pace with the vertical growth of the sphagnum. The same is true of the shrubs *Chamaedaphne* and *Andromeda*, and a number of other species (fig. 4). Individuals growing apparently upon the moss can nearly always be traced downwards to the substratum. Sooner or later most of these fail in the competition. *Chamaedaphne* persists however, possibly aided by the germination of new individuals upon the moss itself. A new group of plants now appears, which is destined finally to cause the death of the sphagnum. First are relatively insignificant species such as the Cranberry, Creeping Snowberry, Round-leaved Sundew, and others. Most important is the Labrador Tea (*Ledum groenlandicum* Oeder), which becomes established upon the highest portions of the sphagnum masses and whose root system is strictly confined to them. Its influence lies in the effective shade which it casts upon the light requiring sphagnum, and the great amount of waste which falls from it and accumulates upon the surfaces beneath. Accompanying *Ledum* or often preceding it, and sometimes nearly as important, are several mosses: *Polytrichum strictum* Banks, *Aulacomnium palustre* (L.) Schwaegr., and *Calliergon Schreberi* (Willd.) Grout, in order of their usual first appearance. Young plants of these species start among the sphagnum heads and spread over the mass in all directions. Stoppage of upward growth of the latter moss follows as a necessity. Along the edge of the bog forest, at the

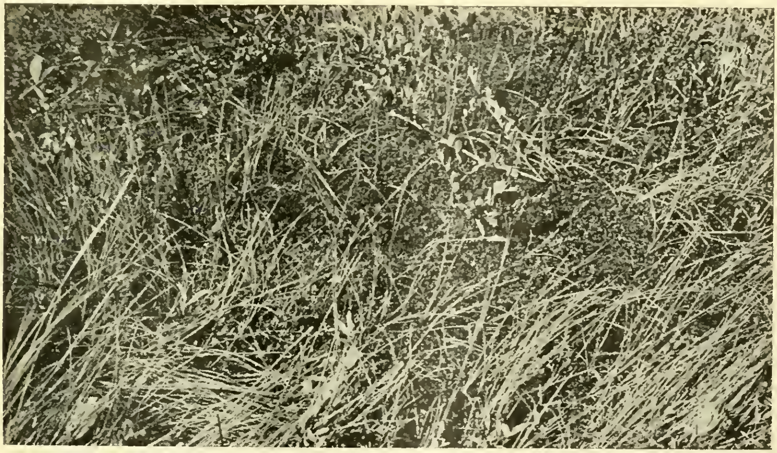

Fig. 4 Bog on Raspberry Island. *Carex limosa* and *Chamaedaphne calyculata* buried by sphagnum which has invaded the sedge mat, and keeping pace with the growth of the moss by upward elongation.

back of the *Ledum* zone there is frequently a broad belt where *Calliergon* covers the surface completely. Investigation in such a case will show that this species is merely a thin carpet overlying masses of dead sphagnum sometimes a meter in depth. In a few bogs *Camptothecium nitens* (Schreb.) Schimp. was found invading the sphagnum in a similar way. *Hylocomium proliferum* and *Hypnum crista-castrensis,* mosses of the climax forest often follow soon after *Calliergon.*

Under certain conditions which were not satisfactorily determined, the sphagnum is able to hold its own against the invading mosses, and even to become an invader itself. Tongues of the moss were frequently found advancing into portions of the bog forest previously free of sphagnum (fig. 5); and in one case a mass was discovered actually climbing a slope of 25° into the climax forest itself. It had reached a distance of ten meters from the true bog margin and had attained a height of four and a half meters above its level. It was entirely covered with a thick but stunted growth of *Ledum.*

Fig. 5 Bog near Park Place. A mass of sphagnum invading the bog forest, surrounding trees and logs, and burying the herbaceous vegetation.

The bog forest develops upon the area previously dominated by the *Sphagnum-Ledum* combination, and in the "marginal zone" as well. The latter is a depressed region, more or less completely encircling the bog, and commonly free of sphagnum unless invaded by it as described in the last paragraph. It is a widely distributed feature of sphagnum bogs, and various explanations have been suggested for it, which need not be discussed here. In the marginal zone of all bogs that possess it, and in the bog forest in general of those without abundance of sphagnum, the moss contingent is remarkable for its variety rather than for its bulk. Conditions of moisture and shade are apparently at the optimum for the average moss requirements. In one small area twenty-two species were collected, and the complete list of these will be of interest.

Aulacomnium palustre (L.) Schwaegr.
Aulacomnium palustre var. *polycephalum* B. & S.
Calliergon Richardsonii (Mitt.) Kindb.
Calliergon Schreberi (Willd.) Grout.
Campylium stellatum (Schreb.) Bryhn.
Dicranum flagellare Hedw.
Dicranum fuscescens Turn.
Dicranum scoparium (L.) Hedw.
Dicranum undulatum Ehrh.
Drepanocladus uncinatus (Hedw.) Warnst.
Georgia pellucida (L.) Rabenh.
Hylocomium proliferum (L.) Lindb.
Hypnum crista-castrensis L.
Leucobryum glaucum (L.) Schimp.
Mnium punctatum L. var. *elatum* Schimp.
Mnium subglobosum B. & S.
Oncophorus Wahlenbergii, Brid.
Plagiothecium denticulatum (L.) B. & S.
Plagiothecium turfaceum Lindb.
Pohlia nutans (Schreb.) Lindb.
Sphagnum papillosum Lindb. var. *intermedium* (Russ.) W.
Splachnum ampullaceum L.

We have seen that the mosses of the climax forest have already established themselves to some degree. The same is true of the climax trees, which are often found growing with the bog trees even during the open bog stage. The transition to the climax state consists merely in the gradual increase of the characteristic species, trees, mosses, and other plants, at the expense of the bog forest forms, until the dominance of the former is complete.

The successional ranges of twenty-three important species of the Bog Succession are shown in figure 6.

III. THE CLIMAX FOREST

The climax forest is not homogeneous throughout in character and appearance. It is made up of small patches of diverse

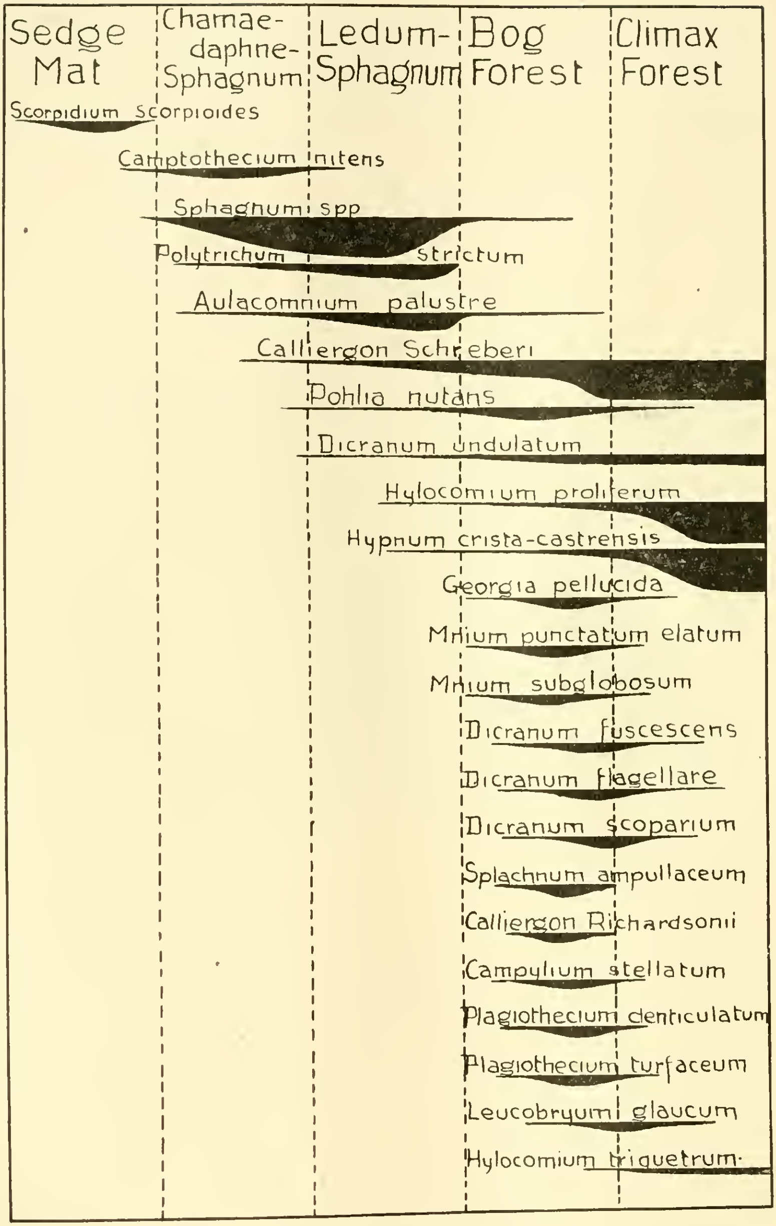
Sedge Mat
Chamae-daphne-Sphagnum
Ledum-Sphagnum
Bog Forest
Climax Forest
Scorpidium Scorpioides
Camptothecium nitens
Sphagnum spp
Polytrichum strictum
Aulacomnium palustre
Calliergon Schreberi
Pohlia nutans
Dicranum undulatum
Hylocomium proliferum
Hypnum crista-castrensis
Georgia pellucida
Mnium punctatum elatum
Mnium subglobosum
Dicranum fuscescens
Dicranum flagellare
Dicranum scoparium
Splachnum ampullaceum
Calliergon Richardsonii
Campylium stellatum
Plagiothecium denticulatum
Plagiothecium turfaceum
Leucobryum glaucum
Hylocomium triquetrum

Fig. 6

aspect which represent stages in an endless chain of permutations, the total result of which is that the forest as a whole remains the same, although a given area is continually changing. Thus we may find side by side an extremely dense group of young trees with no undergrowth, an area with scattered large trees giving moderate shade and with a thick growth of mosses, and a similar area with Ground Hemlock (*Taxus canadensis*) instead of the latter. Masses of wreckage resulting from windfalls are frequent everywhere.

Three elements of vegetation are concerned in these changes: first, the trees, mainly balsam fir, paper birch, and white spruce; second; the undershrub ground hemlock; third, the mosses *Calliergon Schreberi*, *Hylocomium proliferum*, and *Hypnum crista-castrensis.* The interrelations of these elements will best be understood by tracing the history of a single area.

It will be most convenient to begin with the stage in which the trees are all large and few and scattered. The shade is moderate, and the ground is covered either by a thick carpet of the three climax mosses or else by a dense growth of ground hemlock, sometimes almost impenetrable. With passing years the trees decrease in number and the shade becomes correspondingly less; and up to a certain point this is favorable to the mosses or ground hemlock, both of which thrive best under rather light shade. Sooner or later windfall is almost certain to take place upon the area: that is, in some severe storm or succession of storms a number of trees are blown down together. The effect upon the undergrowth is frequently disastrous, though in small windfall areas it may survive and even flourish afterward. Ground hemlock sometimes retains possession, preventing for a time the new crop of trees that normally follows. After the mass of débris has partially disintegrated, conditions become favorable for a fresh generation of trees, which usually start in dense clumps, shading the ground completely and thus inhibiting the establishment of undergrowth of any kind, including even seedlings of their own species. Many trees die through the stress of competition and the shade gradually lightens. Mosses come in, or else ground hemlock, and increase as conditions become more favorable; and the cycle is now complete.

The factors which determine whether mosses or ground hemlock shall become dominant are not certain. One fact may be mentioned however that may suggest at least a partial explanation. Mosses are decidedly more abundant in parts of the forest which are much exposed to the wind, such as the outer row of islands bounding Rock Harbor on the southeast, where windfalls are consequently very frequent and extensive. Ground hemlock is more abundant in sheltered situations where windfalls are comparatively rare—where the trees drop one by one without seriously disturbing the lower vegetation. The explanation here suggested is that the development of an abundant moss vegetation requires a comparatively short time, and may thus be accomplished in the brief intervals between windfalls characteristic of exposed situations; while for the ground hemlock to establish itself in sufficient abundance and luxuriance to obtain and maintain dominance requires a long time and comparatively stable conditions, obtainable only in very sheltered localities.

Equilibrium is thus maintained in the forest as a whole, and it is to be considered as the permanent climax society in spite of the state of continual change existing within it.

Of the three elements the mosses are the weakest in the competition. The tree element is able to exclude both the ground hemlock and the mosses; the ground hemlock when abundant excludes mosses and holds its own against the trees; while the mosses are able to exclude neither. It is nevertheless true that the mosses, because they quickly establish themselves whenever conditions permit, and through their accumulation of humus and conservation of moisture, are immensely important to the maintenance of the climax forest.

SUMMARY

There is upon Isle Royale a definite succession of mosses, continuous in the Rock Shore Succession, from the very beginning to the establishment of the climax forest; and in the Bog

Succession, from the sedge mat to the climax. In some stages mosses are relatively unimportant, while in others they form the bulk of the vegetation.

Mosses play an important part in the successional development of the climax forest, their principal rôles being the accumulation of humus and conservation of soil moisture.

Mosses are of the greatest successional importance as pioneers upon the bare surfaces of the rock shores, in the sphagnum-shrub stage of the Bog Succession, and in the climax forest, the number of species being few in all three cases. They occur in the greatest number of species in the stage just preceding the climax in both successions: the mesophytic boulder-cliff stage of the Rock Shore Succession and the bog forest stage of the Bog Succession.

Calliergon Schreberi is the most widely distributed species, and contributes more than any other moss to the establishment of the climax forest, in both Rock Shore and Bog Successions.

A SCHEMATIC REPRESENTATION OF THE WATER RELATIONS OF PLANTS, A PEDAGOGICAL SUGGESTION

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The extreme complexity of the relationships which determine the moisture content of the growing regions and other active parts of the ordinary plant renders it somewhat difficult to bring these relationships clearly to the mental grasp of students of plant physiology. The fundamental importance of these water relations is generally acknowledged, but current treatises as generally fail to present anything like a logically balanced consideration of the diverse conditions therein involved. The outline here presented was first prepared as an aid to research in this field and was subsequently arranged in the form of a diagram, it is here given the form of headings and sub-headings, a form of presentation better adapted to the use of the printed page. Some of the evidence upon which certain points are based has not yet been published, but will shortly appear. The scheme makes no pretense to completeness; it attempts to exhibit in barest outline the *main* factors which appear to determine the moisture conditions in the active parts of the ordinary rooted plant.

An important pedagogical feature of this scheme is the clearness with which it brings out the purely artificial character of our conventional distinction between the organism on the one hand and its environment on the other. The innumerable series of chains of causes and effects, wherein the effect of one cause is itself the cause of another effect, and so forth, reach into and through the plant without reference to its spatial limitations. Thus, the water in a "storage organ" is undoubtedly within the plant and is nevertheless to be reckoned as an environmental condition when we consider the phenomena of growth at the expense of this water. The water in the interior of a cactus which puts forth flowers and produces fruit without any advent of moisture from the outside, stands in the same relation to the transpiring and growing tissues as does the actually external soil moisture to the similar activities in a non-succulent form. In the scheme below, internal conditions are denoted by an asterisk.

The study of this whole subject of water relations forms an excellent exercise in applying to organic phenomena the principles of physical equilibrium and the general theory of physical causation.

The requisite water content for the activities of any tissue depends in general upon the following condition which may be stated as a ratio, I = II:

I. The rate of renewal of free water in the active parts must, in general, be equal to

II. The rate of removal of free water from the active parts.

I. The rate of water renewal depends upon
  A.* The rate of liberation of water within the plant, which depends upon:
    1.* Rate of chemical formation of water, as by respiration, depending largely upon temperature (usually negligible).
    2.* Rate of physical liberation of water, as by cell shrinkage, death, etc. (usually negligible).
  B. The rate of water entrance from without, which depends upon:
    1. Power of the soil (or other water-supplying medium) to deliver water, per unit of its cross sectional area. This depends upon:
      (1) Force of adhesion manifested between soil particles and soil water (resistance to water movement), which depends upon:
        a. Size and form of soil particles.
        b. Nature of soil particles.
        c. Arrangement of soil particles.

- (2) Thickness of soil water films (soil moisture content). This depends upon:
  - a. Permeability of upper and lower soil surfaces to water (percolation drainage).
  - b. Position of subterranean water table with reference to soil surface.
  - c. Slope of the two soil surfaces (slope, drainage).
  - d. Climatic conditions of the habitat. These involve:
    - d¹ Evaporating power of the air, which depends upon:
      - d¹ (1) Temperature.
      - d¹ (2) Humidity.
      - d¹ (3) Air movement.
    - d² Seasonal distribution of rainfall.
    - d³ Amount of rainfall and rapidity of fall in the separate showers.
    - d⁴ Rate of influx of radiant heat to the soil surface. The latter depends upon:
      - d⁴ (1) Intensity of sunshine.
      - d⁴ (2) Quality of sunshine.
      - d⁴ (3) Radio-absorptive power of the soil surface (color, etc.)

2.* Power of roots to absorb water, which depends upon:

- (1)* The water-imbibed condition of the peripheral cell walls (whether thoroughly imbibed or not), which depends upon:
  - a. The general rate of water entrance from soil (B, in general).
  - b.* Rate of water conduction away from absorbing surfaces (toward the transpiring surfaces).

            - (2)* Extent of root system (amount of root surface).
            - (3)* Structure of root system (kind of root surface).
        - 3.* Rate of advance of roots through the soil (root growth).

II. The rate of water removal depends upon:

- A.* The rate of fixation of water within the plant, which depends upon:
    - 1.* Rate of chemical fixation, as by photosynthesis (usually negligible).
    - 2.* Rate of physical fixation, as by growth (usually negligible).
- B. The rate of water outgo from the plant. This depends upon:
    - 1.* Rate of water-loss by external secretion, as of guttation, nectar secretion, etc. (usually negligible).
    - 2.* Rate of loss of water vapor from aërially exposed surfaces (transpiration). This depends upon:
        - (1) The water extracting power of the aërial environment, depending upon the climatic conditions of the habitat (see I,B,1, (2), d), comprising:
            - a. Evaporating power of the air, which depends upon:
                - a¹ Temperature.
                - a² Humidity.
                - a³ Air movement.
            - b. Influx of radiant heat to transpiring surfaces, which depends upon:
                - b¹ Intensity of sunshine.
                - b² Quality of sunshine.
                - b³* Radio-absorptive power of transpiring parts (color, etc.).

- (2)* Transpiring power of aërially exposed surfaces, which depends upon:
  - a.* Extent of these surfaces.
  - b.* Structure of the transpiring parts (frequency of stomata and lenticels, hairiness, cuticularization of cell walls, etc.).
  - c.* The condition of these parts, comprising:
    - c^1* Openness of stomata and of lenticels.
    - c^2* Water-imbibed condition of the aërially exposed cell walls (their water content). This depends upon:
      - c^2 (1)* The general rate of transpiration (II, B,2).
      - c^2 (2)* The rate of conduction of water to these membranes, from the regions of supply (I,B,2,(1),b).

BOOKS AND CURRENT LITERATURE

Flora of California.—The third part (the second in systematic consecutiveness) of Jepson's Flora of California,[1] which has just appeared contains the families from Gnetaceae to the beginning of Cyperaceae. Much the larger part (124 pages) is devoted to the Gramineae, and is contributed by Hitchcock. He recognizes 71 genera and 324 species, a considerable increase over the 62 genera and 174 species enumerated by Thurber, in 1880, in the Botany of the Geological Survey, the last work which embraced the flora of the entire state. To a certain extent this represents a difference in the conception of taxonomic values, but mainly it illustrates the fuller knowledge of California plants which has been attained in the last thirty years. Another interesting comparison may be made with the Gramineae of the seventh edition of Gray's Manual, where the family is elaborated by the same hand, and at a contemporary date. The number of genera there included, 83, is larger but the number of species, 246, is much smaller. It is certainly unexpected to find that the grass flora of the single state of California is so much more diversified in species than that of the far larger region included in the Manual. These comparisons are still further emphasized in the subjoined table of those genera which are accredited in Jepson's Flora with

Flora of California

	JEPSON	THURBER	GRAY
Poa	30	10	17
Bromus	22	6	16
Agrostis	18	12	6
Festuca	16	7	10
Stipa	15	11	5
Panicum	14	5	7
Melica	13	8	5
Calamagrostis	11	9	9

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[1] Jepson, Willis Linn, A Flora of California. Part 3. Gnetaceae to Cyperaceae (*Cyperus*). Gramineae, by A. S. Hitchcock. Pp. 65–192. San Francisco, Cunningham, Curtis and Welch, 1912. ($1.50.)

more than ten species. The second column shows the number of species recognized by Thurber, and illustrates the increase in knowledge of the state flora; the third column, giving the species in the new Gray's Manual, is a partial indication of the difference of development which these leading genera have attained on the two sides of the continent. That this large increase is not the result of reckless species-making is evident from the fact that but four new species are proposed in the work, and fewer previously described varieties raised to specific rank, while a considerable number of both species and varieties are reduced to synonomy. The lack of a comprehensive manual of the Californian flora has been nowhere more painfully evident than in the study of the grasses, and it will prove a great satisfaction to all students to have this want so satisfactorily supplied.—S. B. Parish.

Foliar Periodicity in the Tropics.—Volkens has published[1] a detailed series of observations on the fall and renewal of foliage in 100 tropical trees growing in the Buitenzorg Garden, together with a digest of his own results and those of Wright, obtained in Ceylon. The periodic phenomena of tropical foliage have never before been treated as a physiological problem, and Volkens has accordingly done much toward clarifying the subject, in spite of the confessed inconclusiveness of his results. He finds that the majority of tropical trees have a definite annual periodicity of leaf behavior, which however differs greatly between different species both in its character and in the time of its occurrence. A minority of trees show a continuous foliar activity. In very many species there are differences of foliar behavior between different individuals, different branches of the same individual, and individuals of different ages, although such differences are usually due merely to a slight lack of synchronism. Volkens finds that the considerable differences of rainfall between winter and summer at Buitenzorg do not bring the activities of any majority of trees into unison, although he acknowledges that the monthly fluctuation of rainfall does not mean an equal fluctuation of soil moisture. He finds the annual temperature curve too slight in its amplitude to account for any of the foliar phenomena, and he dismisses as untenable the theory of A. M. Smith that fluctuation in the salt content of the soil water is the determining factor. An examination of the starch content of twigs and stems in newly foliated and in defoliated trees

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[1] Volkens, G., Laubfall und Lauberneuerung in den Tropen. Pp. 142. Berlin, Borntraeger, 1912. (Mk. 3.80.)

showed large quantities to be present in both cases, and led Volkens to abandon his working hypothesis that the fall of a leaf is due to the cessation of the withdrawal of the products of photosynthesis through their heavy accumulation in adjacent woody tissues. High sap pressure at the time of foliation has been found to occur in numerous tropical trees, accompanied by a slight and temporary increase in stem diameter. Using this increase as a criterion of sap pressure, Volkens failed to find its occurrence in any of some six trees on which measurements were made.

The author's general conclusions are that each species of tree has a rhythmic periodicity of behavior, dependent primarily on internal physiological conditions—and therefore subject to slight individual variations in chronology—but dependent secondarily on climatic conditions. A uniform climate like that of Buitenzorg permits a wide range of behavior; climates with more marked seasonal differentiation show a more pronounced marshalling of the phenomena.—F. S.

METABOLIC WATER.—The subject of metabolic water, water which is chemically produced within the cells of animals and plants, has recently received at the hands of S. M. Babcock,[1] a much more thorough and adequate treatment than we have heretofore come upon. The phenomenon of water *production* appears to be much more important in general physiology than is usually implied in current treatises.

The author calls attention to the well known, but usually neglected, fact that large amounts of water are produced (1) by oxidation (both in aërobic and anaërobic respiration) in living cells, and (2) by dehydration of hydrated compounds. The complete oxidation of starch or cellulose gives water amounting to 55.5 per cent of the original weight of the material. Dextrose gives 60 per cent and most fats over 100 per cent. While the oxidation products from protein decomposition are mainly resynthesized in plants, the production of urea and uric acid from proteins in animal metabolism results in the liberation of chemically formed water amounting to from 42 to 53 per cent of the original weight of proteins decomposed. As examples of metabolic water produced by dehydration, it may be mentioned that when glucose is converted into starch or cellulose 10 per cent of the original weight appears as water; while the formation of cane sugar from glucose sets free water amounting to 5 per cent of the weight of glucose. Water

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[1] Babcock, S. M., Metabolic Water: its production and role in vital phenomena. Univ. of Wisconsin Agri. Exp. Sta. Research Bull. No. 22, pp. 87–181. March 1912.

is also chemically produced in the formation of the complex proteins from peptones, polypeptides, amino-acids, etc.

Babcock's studies relate largely to the processes of germination in seeds and of ripening in fruits but he records a number of extremely interesting observations on the water relations of such forms as the clothes moth (*Tinea pellionella*, Linn.), the bee moth, the pea weevil, etc. Larvae of the clothes moth containing from 57 to 59 per cent of moisture developed upon air-dry food material containing from 3.66 to 9.08 per cent of water, these organisms receiving no liquid water at any time. The bee moth (*Galleria mellonella*, Linn.) thrives with even less moisture in the food. Larvae containing about the same percentage of water as those of the clothes moth just mentioned, developed upon comb containing but 1.85 per cent of moisture. The conclusion is reached that most of the water contained in these organisms must have arisen from the decomposition of the food material; it must be considered as metabolic water.

The studies which Babcock has carried out on seed germination, especially with maize, lead him to the generalization that low percentage of germination in maize is often due to lack of soluble carbohydrate in the seed. This, in turn, is regarded as due to lack of diastase, which is supposed to be produced only with normal respiration. Hence low viability is traced to lack of normal respiration, due to inadequate supply of oxygen to the stored seed. This idea is supported by such observation as the following: Maize of low germinating power may be made to germinate quite normally if soaked in a diastase solution, as has already been noted by Waugh. Babcock repeated these tests and discovered further that a 3 per cent solution of glucose has the same beneficial effect as does the diastase. Furthermore, maize seed of low viability, if soaked in a 1.5—or 3—per cent solution of hydrogen peroxide, is greatly improved, this being apparently due to the acceleration of the processes of oxidation by the oxidizing agent. Incidentally, the hydrogen peroxide prevents the growth of moulds and the use of a 1.5 per cent solution of this substance is to be recommended in starting germination. Seeds like maize, which do not normally germinate under water, may be made to do so under a weak solution of the peroxide.

Many interesting and significant observations on the hydrophysiology of plants are brought forward in this publication, but these cannot be taken up here. The paper should, on the whole, be considered as a landmark, and should stimulate research along a large number of different lines.—B. E. L.

NOTES AND COMMENT

For many years we have had with us popular, semi-popular and even scientific books in which plants are tacitly or overtly credited with the human attributes of foresight, prudence, ingenuity, and fear. Indeed, we have recent texts and very recent articles in creditable scientific journals in which occur expressions implying that this or that activity in plants is of a purposeful character, directed to the attainment of an advantage or to the evasion of an impending harm. The use of such expressions indicates that their author is blind to the causality which underlies all natural phenomena and that he sees ahead of the army of scientific workers an impregnable wall at which they must halt and disband, rather than a limitless field over which they may deploy in every direction. While the existence of such a wall is in accord with the working philosophy of some biological investigators, it is highly probable that it is the inertia of language and phrase which is chiefly responsible for the survival of these objectionable expressions. To many writers it seems difficult to make statements about plant behavior without resorting to them, and to others it seems excusable to use them together with an explanation or an apology. Two texts have appeared during the past year—The Chicago Text-Book and Duggar's Plant Physiology—in which a studied effort has been made to evade homocentric phrases and words, and these books will do much to persuade the doubters that it is possible to dispense with them. The authors of these texts have not only avoided expressions which are flagrantly teleological or homocentric, but they have expunged words which have merely "a bad flavor" in this connection, words, that is, which have too close an association with the literature and ideas of the homocentric period, and words which are of objectionable etymology.

There is no doubt of the fact that in order to get clear of objectionable ideas we must abandon the vocabulary in which these ideas were clothed. We are glad to see "moisture loving" and "drought resistant" go. We are willing to abandon "function" because of its intimation of purpose, and to speak of "conditions" rather than of "stimuli," because the former word connotes something wholly understandable. We cannot, however, go so far as to feel that it is equally important to discard Latin or Greek derivatives because their etymological meaning carries an objectionable implication. For example the word "anemophilous" is an undesirable one when translated, but as actually used in botanical literature it carries no homocentric notions, and merely indicates that the wind is the physical factor by means of which pollination is effected. Whenever an English word or phrase has become objectionable as a vehicle for scientific expression for any reason which relates to our working philosophy, the word should be discarded. If a Greek or Latin derivative, when translated into its English equivalent, sounds objectionable and if it is also in bad odor because of the conceptions in connection with which it has been coined and used, let us abandon it, but for the latter reason and not for the former.

The interest which is taken by the agriculturists of the United States in the value of natural vegetation as an index of crop possibilities, places us in a position to appreciate the practical value of the work of Engler in which he has described the distribution of the vegetation of Africa. The rapidity with which the best portions of Africa are being opened up to settlement by Europeans makes it particularly fortunate that all the evidence which vegetation is capable of giving as a guide to settlement and agricultural prospecting be given at as early a date as possible. It is not difficult to imagine the benefit which would have arisen from an equally good knowledge of the distribution of the natural vegetation of North America at a corresponding period in its settlement. At that time, however, the state of botanical science was such that the exploitation of the flora was the only botanical activity directed against the relatively new continent. Africa, however, has had its awakening at a more opportune time in this respect. Not only has the Berlin Garden carried on its floristic work, of great scientific importance, but it has had in view also the aiding of colonists in its four African possessions by the investigation and publication of the ecological relations of the natural vegetation. There has been no more conspicuous example of the material service which ecological work of this character is able to render to agriculture and the botanical industries.

NOTES ON THE GEOLOGICAL HISTORY OF THE WALNUTS AND HICKORIES

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The walnut family (Juglandaceae), which in the popular mind is fully rounded out by the enumeration of the walnut, butternut, hickory and pignut, while relatively small, is by no means as limited as this might indicate. According to current interpretations there are six genera and about forty species widely scattered throughout the warmer parts of the north temperate zone and penetrating some distance south of the equator along the Andes in South America, and in the East Indies.

The Juglandaceae are of considerable interest for a variety of reasons, chief among which, aside from their great economic importance, are their long line of ancestors reaching back some millions of years to the Mid-Cretaceous, and the former wide range and abundance of these ancestors, which also serves to explain the curious geographical distribution of the still existing species. They are also interesting because of the much discussed question as to whether their morphological characters shall be interpreted as primitive or as mere simplifications of a more highly organized stock.

Not all of the genera have adopted the same methods of seed dispersal and certain genera have kept the seed part of their fruits comparatively small and light, thus enabling them to produce large numbers of seeds with the same expenditure of energy required for a single walnut. Furthermore, instead of depending altogether upon chance for the dissemination of their latent progeny, the bracts which are normally present have developed enormously and serve as wings. This is especially true in the genera *Engelhardtia* and *Oreomunnea* and will be referred to on a subsequent page.

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The fruits unmistakably indicate the genera—those of the hickory have smooth shells and a husk which splits more or less, the walnuts and butternuts have a very rugose surface and an entire husk, while *Engelhardtia*, *Oreomunnea*, and *Pterocarya* have small compound winged fruits. The leaves are always compound, and may be distinguished from those of the ash by being alternately arranged instead of opposite. There are numerous other details which enable the student to distinguish between the leaves of the different genera and species. It will be convenient to take up each genus separately and describe something of its present range and such portion of its geologic history as is known.

THE GENUS HICORIA

The hickories are now referred to the genus *Hicoria*, proposed by Rafinesque in 1808, although many systematists, especially in the old world, still use the name *Carya* proposed by Nuttall in 1818 and universally used until about twenty years ago.

The hickories occupy a unique economic position, for while the consumption of this wood is less in quantity than that of some of the other hardwoods such as white oak or yellow poplar, or of various coniferous trees like the cypress or the pines, it shares with the black walnut the distinction of being the most costly American wood. Hickory, while not remarkable for beauty of color or of grain, will probably be the most difficult wood to replace when the approaching shortage becomes more acute, since it combines weight, hardness, stiffness, strength and toughness to a degree unequaled among commercial woods. The Forest Service estimates that the consumption of hickory for lumber, spokes, tool-handles, rims, shafts, sucker rods, etc., amounted to 450,000,000 board feet during 1908, exclusive of the large amount used as fuel, estimated at about 1,000,000 cords—for hickory is also the best American fuel wood.

The genus *Hicoria* is entirely confined to North America in the existing flora, more particularly to the eastern United States, although there is an indigenous species in Mexico (*Hicoria mexicana*), and three or four other species reach their northern limit of growth beyond the Great Lakes in Eastern Canada.

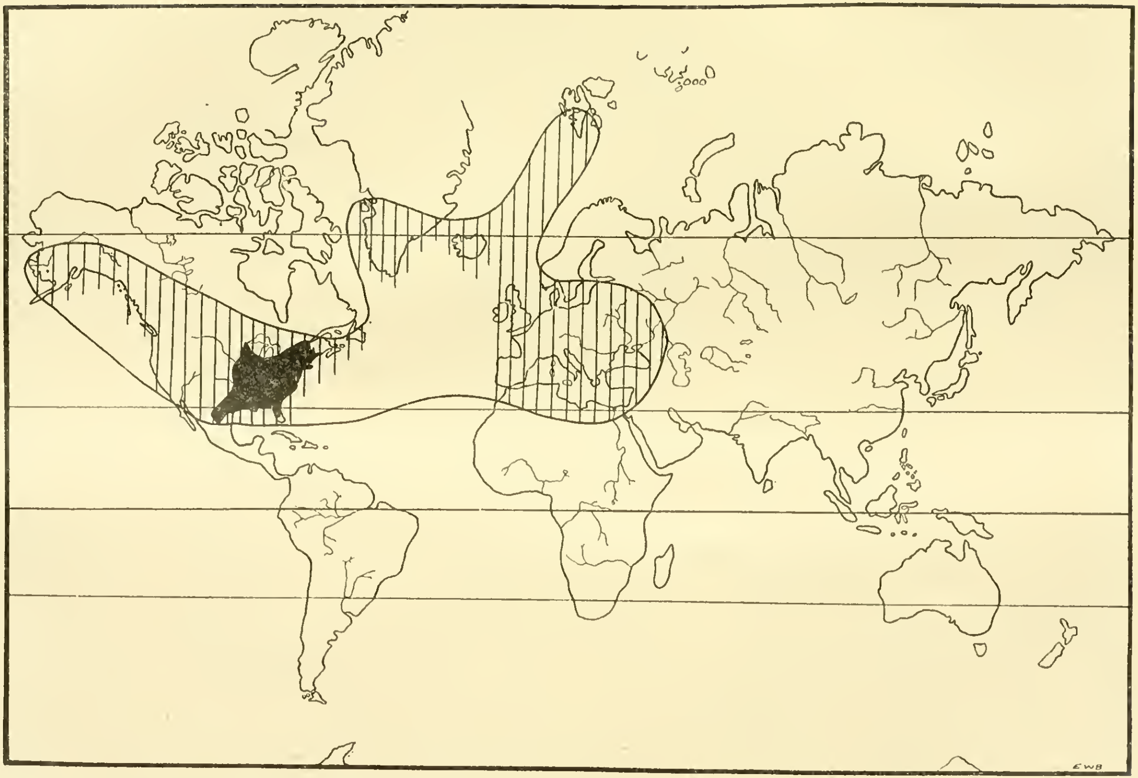

Fig. 1 Sketch map showing the area of distribution of the existing species of *Hicoria* (solid black) and the area over which the genus is known to have spread during its past history (vertical lining).

The existing species number from eight to fifteen, according to the rank assigned to the varieties of the eight or nine easily distinguished and main types. They fall naturally into two groups—the true hickories and the pecan hickories—groups which were already clearly defined in pre-glacial Pliocene times.

The true hickories are fine, slow growing trees of in general temperate dry soils with hard strong wood. The buds are full, with overlapping scales, and the nuts are generally thick shelled and thick husked, while the leaflets are from three to nine in number. The pecan hickories are trees which require warmth and moisture, and possess relatively weak wood. The buds are thin and narrow without overlapping scales and the nuts have thin shells and thin husks while the leaflets are numerous, slender, and falcate.

Over a score of fossil species have been described. Unlike the walnut the hickory is not known with certainty from the Cretaceous, but it is present in every early Eocene deposits in Wyoming and on the Pacific coast. Hickories occur in the upper Eocene of Central Europe and there is a fine large leafed species from deposits of this age at Kukak Bay, Alaska. The Oliogocene occurrences are largely referred to *Hicoria ventricosa* which is abundantly represented by leaves and fruit in the Oliogocene browncoal deposits of Europe. The late Miocene appears to have been the period of widest extent of the hickories. From deposits of this age about a dozen species are known. Trees were scattered all over Europe and the genus extended to Iceland, Greenland and Spitzbergen. In North America there were species in Oregon and California, in Colorado and in Vermont. A species very close to the existing pecan occurs in the late Miocene of New Jersey.

During the succeeding Pliocene period the hickories are as abundant and vigorous as in the late Miocene in Europe although their northern limit appears to have become somewhat restricted. Even as late as the Upper Pliocene several species of hickory are abundant in Italy and Germany but none survived the Ice Age on that continent.

A species resembling the pecan is represented by both leaves and nuts in a late Pliocene lagoon deposit in southern Alabama. In America there are numerous Pleistocene records, the leaves being preserved in the clay deposits of the river terraces and the fruits in the buried swamp deposits. The following still existing species are recorded from the Pleistocene of this country: *Hicoria pecan* from the old Mississippi bluffs at Columbus, Kentucky: *Hicoria alba* from a cave in Pennsylvania and from the interglacial beds near Toronto, Canada: *Hicoria aquatica* from North Carolina; *Hicoria ovata* from Pennsylvania, Maryland and North Carolina: *Hicoria villosa* from Alabama, and *Hicoria glabra* from Pennsylvania, Maryland, Virginia and North Carolina.

The accompanying map (fig. 1) shows the area occupied by the existing species in solid black and the known Tertiary range by vertical lining. It seems probable that the genus spread eastward over Asia but the latter continent has been so little explored that no records are known.

While the Ice Age exterminated the hickories from Eurasia the genus survived safely in North America and is in no danger of extermination except by the ax of the woodman. Their great tolerance of shade and their ability to respond to the stimulus of increased light combined with their longevity are important factors in their continued existence. While the rodents consume many of the fruits they have probably done so during the whole history of the genus, for nuts gnawed by squirrels are not infrequent in Pleistocene deposits. This is not an unmixed evil for various rodents not only distribute the species but bury the nuts in forgotten places where they are almost sure to grow. Before the advent of the "civilized ax" many venerable old giant hickories were scattered through our American forests and there are numerous records of immense trunks showing 350 or more annual rings.

THE GENUS JUGLANS

The name *Juglans* is a contraction of *Jovis glans* or nut of Jupiter and the specific name of the species known to the ancient Greeks and Romans is *regia*, or royal, and is fittingly applied to the magnificent tree which has been so commonly planted throughout the old world for so many centuries. Nuts are found under the Swiss lake dwellings of the Neolithic period. Our two eastern American species are equally royal trees. The black walnut, *Juglans nigra* Linné ranges from Massachusetts to southern Ontario, Minnesota and eastern Kansas and southward to Florida and Texas. Its rich edible fruits and handsome dark wood have made it a favorite wherever furniture is manufactured and in consequence the tree is becoming scarce. It makes a fine growth when planted abroad and undoubtedly was a native of Europe in pre-glacial time, as is shown by nuts preserved in the Pliocene deposits of that country, which are indistinguishable from the existing species. The butternut or white walnut, *Juglans cinerea* Linné yields a wood that is much inferior to the black walnut, but its fruit is equally attractive. It ranges somewhat further to the northward and not so far to the southward as the black walnut, being found from New Brunswick and Ontario to North Dakota and southward to Delaware. In the Alleghanian region it extends southward to Georgia and northeastern Mississippi and it is also found in Arkansas. It is distinctly not a coastal plain species. Like the black walnut it is very closely allied to certain pre-glacial European forms. There are several other American species with a more limited range. They are all trees, and include a Jamaican form and one or two species found in the Andes of Bolivia. A species of Northern Mexico, *Juglans rupestris* Engelmann, extends into Arizona, New Mexico and the Rio Grande part of Texas and there is a single species *Juglans californica* Watson along the Pacific Coast in California. The range of the latter is limited and its seedlings are scarce, the nuts being largely consumed by rodents. There is also a species of walnut on the opposite shore of the Pacific in Manchuria.

The genus Juglans is apparently one of the earliest of the still existing dicotyledonous genera to appear in the fossil record, leaves suggesting it having been found in the middle Cretaceous. It is well represented in fossil flora from the base of the upper Cretaceous to the present, the former horizon furnishing at least seven species, one of which, *Juglans arctica* Heer ranges from

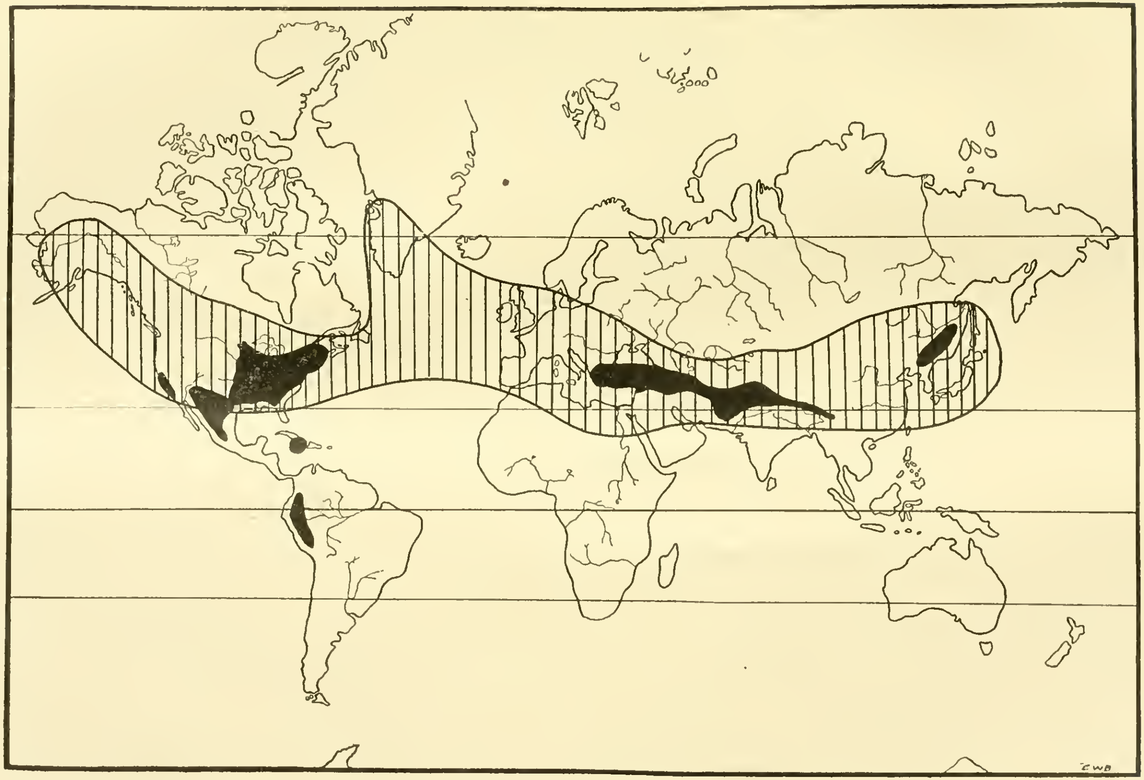

Fig. 2 Sketch map showing the area of distribution of the existing species of *Juglans* (solid black) and the area over which the genus is known to have spread during its past history (vertical lining).

Greenland to Alabama along the Atlantic coast and furnishes a striking illustration of the difference between Cretaceous and present day climates.

There are about twenty-five Eocene species of walnut well distributed over the northern hemisphere. They extend from the Mexican Gulf region to Alaska and Greenland in North America and from Saghalin Island off the east coast of Asia to western Europe in the old world.

The Oligocene walnuts are not quite so plentiful as are those of the Eocene and are almost entirely confined to the old world. This is undoubtedly an expression of the incompleteness of the geological record in North America since there are practically no known Oligocene plant beds in this country.

The Miocene has furnished upwards of two score species, the majority of which are old world forms distributed from Japan to western Europe. This again being due more to lack of records in America rather than to the absence of the genus. In this country nuts are preserved in the curiosuly isolated lignite deposit near Brandon, Vermont. There are species in Idaho, several in California and Oregon, and four in Colorado in the late Miocene at Florissant. Both fruit and leaves are frequently found associated in the various Tertiary deposits and nuts also occur with the leaves in some of the Cretaceous deposits.

The Pliocene species are also numerous, a number of them surviving from Miocene times. In all about twenty-five forms have been recorded from the Pliocene deposits and several of these are very close if not identical with still existing species. From the upper Pliocene of Germany nuts have been collected in the lignite deposits which are exactly like those of the existing American species *Juglans nigra* and *Juglans cinerea.*

Walnuts are not common in Pleistocene deposits but the fruit of *Juglans regia* Linné is recorded from the Pleistocene of southern France, and our own black walnut, *Juglans nigra* Linné, has been found in the late Pleistocene of Maryland and in the Pleistocene river terraces of Alabama. Both of these occurrences are based upon the characteristic nuts preserved in the impure peat of buried swamp deposits.

The walnut of Europe, *Juglans regia* Linné, while extensively planted in southern Europe as well as throughout the Orient is only endemic in Greece[1] and eastward through Asia Minor, Transcaucasia, the northwestern Himalayan region and in northern Burma.[2]

In recent geological times its range has probably become greatly restricted, since the oldest known occurrence of forms identical with the modern tree are in the latest Miocene deposits of central France. A considerable number of occurrences have been recorded from the Pliocene deposits of this region and the central plateau of France was evidently clothed with a considerable stand of walnut in preglacial times. During the Pleistocene this species is known from a number of localities in northern Italy, in Hanover and in southern France (Provence), while the nuts found associated with the Swiss lake dwellings were undoubtedly obtained from wild trees of the immediate neighborhood.

The manner in which the fossils enable us to obtain a vista into the life of bygone days is furnished by recent discoveries in the Egyptian desert. At a time (latest Eocene or earliest Oligocene) when Libya was separated from Europe and Asia by a vast Mediterranean sea the Fayûm was a delta with a heavy rainfall (as shown by the flora) clothed with forests of an indomalayan type, and inhabited by ancestral elephants and other curious forms of ancient animal life. No less than eight kinds of figs as well as laurels and camphor trees have been described from this now arid and dessicated region. Among these fossil plants are the remains of a species of walnut, a striking commentary on the changes which have since taken place.

I have attempted to give a graphic summary of the present and past range of the walnuts on the accompanying sketch map (fig. 2) where the areas of distribution of the existing species (somewhat exaggerated) are shown in solid black. It is possible that the part of the range of *Juglans regia* in southern Asia should be extended eastward over Tibet through northern China

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[1] Mentioned from Greece in Theophrastus and occurrence confirmed in recent years by Heldreich and others.

[2] Possibly also in the mountains of northern China and Japan.

to Japan. All of the known fossil occurrences of walnuts have been plotted and are enclosed within the vertically lined area. Probably the boundary of the southward extension of the genus should be extended, at least sufficiently far to include the South American existing species. It is readily apparent from this map that the modern segregated species are isolated remnants of a once world wide distribution and that the glacial epoch was an unimportant incident in their history on the North American continent, while in Europe, it greatly restricted the range of *Juglans regia* and altogether exterminated one or two additional species of the walnut.

THE GENUS ENGELHARDTIA

The genus *Engelhardtia* was described by Leschen in 1825 and contains about ten species of the southeastern Asiatic area. These range from the northwestern Himalayan region where they extend a short distance north of the Tropic of Cancer through farther India and Burma to Java and the Philippines. The pistillate flowers are small and are grouped in paniculate spikes. They develop into small drupe-like fruits, each of which is connate at the base to a large expanded tri-alate involucre.

A single little known species rarely represented in even the larger herbaria occurs in Central America and is the type and only species of the genus *Oreomunnea* of Oersted. This is much more restricted in its range than are its kin beyond the Pacific. *Oreomunnea* is very close to *Engelhardtia*, and for the purposes of the paleobotanist the two may be considered as identical since they represent the but slightly modified descendants of a common ancestry which was of cosmopolitan distribution during the early Tertiary. The present isolation of *Oreomunnea* furnishes a striking illustration of the enormous changes which have taken place in the flora of the world in the relatively short time, geologically speaking, that has elapsed since the dawn of the Tertiary.

The principle has frequetly been enunciated that when closely related forms are found in the existing flora of the world, restricted in range and isolated from their nearest relatives, or when other existing genera are monotypic, it is quite safe to predict an interesting and extending geological history. *Engelhardtia* proves to be another illustration of this principle, for its peculiar three-winged fruits have been known in the fossil state for almost a century. They were long unrecognized, however, and the earlier students who described them compared them with the somewhat similar winged fruits of the genus *Carpinus* (Betulaceae). With the botanical exploration of distant lands in the early part of the 19th century, specimens of *Engelhardtia* began to be represented in the larger European herbaria, and Baron Ettingshausen, that most sagacious of paleobotanists, as long ago as 1851 pointed out that certain supposed species of *Carpinus* were really fruits of *Engelhardtia.* He returned to the subject in 1858 without, however, actually changing the names of any of the supposed species of *Carpinus* nor does he seem to have been aware of the existence of a living species of *Engelhardtia* (*Oreomunnea*) in Central America.

Since Ettingshausen's announcement a dozen or more fossil species have been described. The oldest known European form occurs in the upper Eocene or lower Oligocene (Ligurien) of France and the species become increasingly abundant throughout southern Europe especially toward the close of the Oligocene and the dawn of the Miocene, Saporta stating that the slabs from the leaf-beds at Armissan in southeastern France are thickly strewn with their peculiar fruits. Fossil forms continue in Europe throughout the Miocene and Pliocene and specimens of late Miocene or early Pliocene age are recorded from Spain, France, Italy, Croatia, and Hungary.

The only described species from America occurs somewhat earlier than any of the European forms, being found in the Lower Eocene (Wilcox Group) of northern Mississippi. The type figure of this form is reproduced in figure 3. This is not the only known species from America, however, as fossil leaves of this or other species occur at the same horizon and an additional species with smaller fruits has recently been discovered by the writer in the Middle Eocene (Claiborne Group) of southern Arkansas.

The accompanying sketch map (fig. 4) shows the existing area of distribution of the genus *Engelhardtia* in the Orient and *Oreomunnea* in the Occident in solid black. These areas are somewhat generalized and exaggerated in order to be visible on so small a scale map.

The areas where Tertiary species of *Engelhardtia* have been found are covered by horizontal lining, and while not as extensive as might be desired, indicate very clearly what was stated a few paragraphs back, that forms closely allied to the modern *Engelhardtia* were widespread during the Tertiary period when the more extensive warm climate enabled them to penetrate more than half way across the North Temperate zone. It seems probable that they also pushed southward into the South Temperate zone but we cannot verify or disprove this theory since practically no fossil plants of Tertiary age have been discovered in South America, Africa or Australia. Another probability is that careful exploration will disclose the living representatives of this widespread Tertiary stock in western Brazil, especially as they have survived in Central America north of the equator.

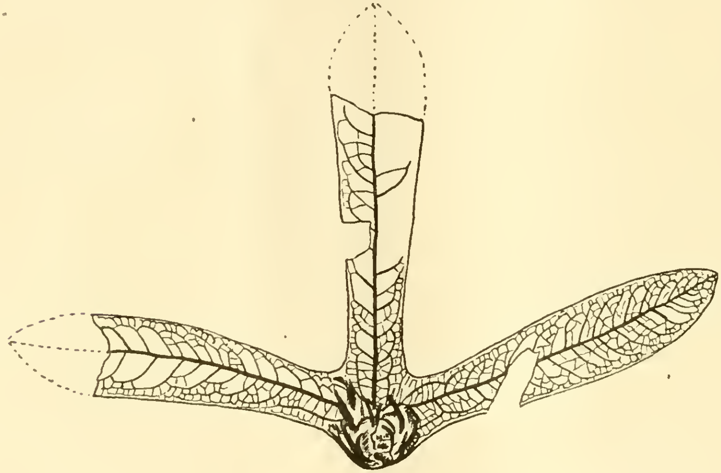

Fig. 3 *Engelhardtia* (*Oreomunnea*) *mississippiensis* Berry, from the Lower Eocene of Mississippi (natural size).

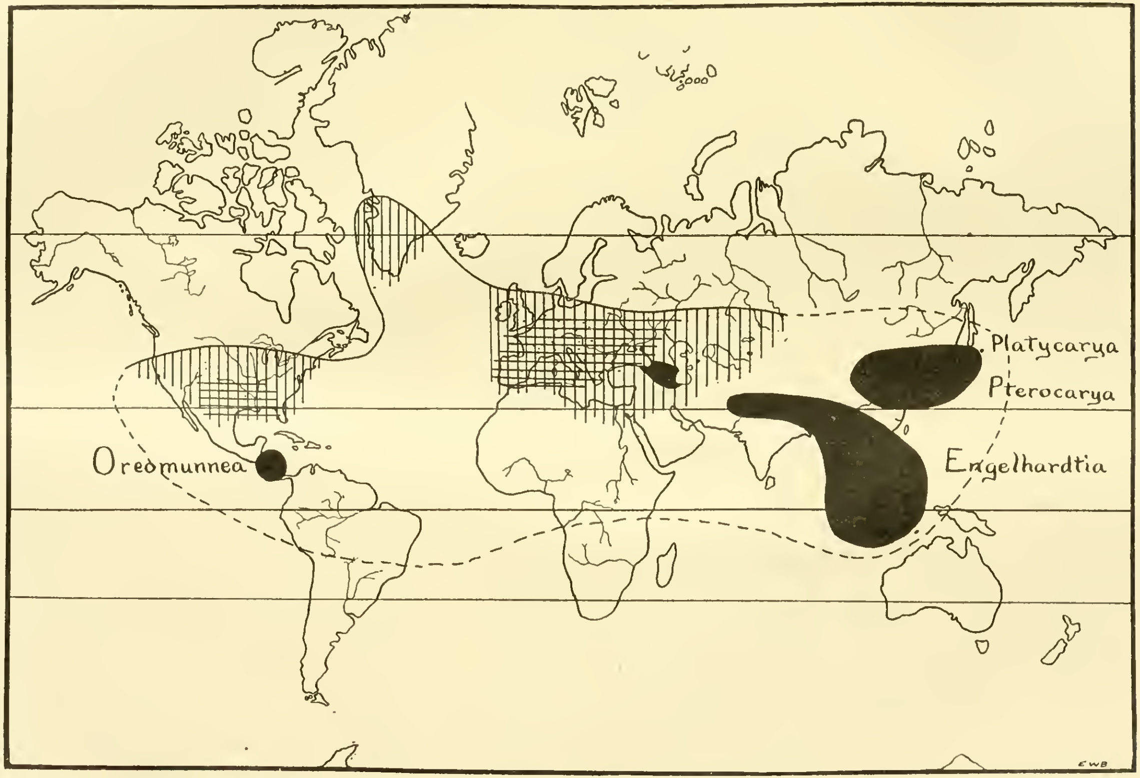

Fig. 4 Sketch map showing the area of distribution of the existing species of *Engelhardtia*, *Oreomunnea*, *Platycarya*, and *Pterocarya* (solid black) and the area over which they are known to have spread during their past history, *Pterocarya* indicated by vertical lining and *Engelhardtia* (including *Oreomunnea*) by horizontal lining.

In a general way *Engelhardtia* fruits are not unlike those of *Carpinus*. There seems to be little occasion for confusion, however, even in poorly preserved fossil material. The fruit proper is decidedly different, although this is seldom well enough preserved in fossils to be decisive. The involucre is also markedly different in the two genera. *Carpinus* involucres are usually smaller with the median wing much wider and longer than the lateral wings and with somewhat different venation.

The margins are also toothed while in *Engelhardtia* they are always entire. I have examined fruits of all the existing species of *Carpinus* and experience no difficulty in readily distinguishing them from those of *Engelhardtia*, the American species of the former being especially different in appearance from those of *Engelhardtia*. I have seen involucres of the old world *Carpinus betulus* from trees cultivated in this country in which the wings had entire or nearly entire margins, but the aspect of the specimens as a whole, because of their different proportions and venation, was markedly unlike *Engelhardtia*, and if they had been found as fossils no competent paleobotanist would have been at a loss regarding their botanical affinity for a single instant.

THE GENUS PTEROCARYA

The genus *Pterocarya* was described by Kunth in 1824. It is made up of three or four species with very circumscribed ranges. The type *Pterocarya caucasica* A. Meyer (*P. fraxinifolia* Spach.) at present is confined to a limited area in Trans-Caucasus, while another species occurs in northern China and one or two in Japan, as shown in a greatly exaggerated way in the solid black areas on figure 4.

The determination of the fossil species from their leaves is beset with difficulties but the fruits are perfectly characteristic and have been found in a number of instances.

The oldest known fossil species is recorded from the Tertiary of Colorado and while the American material that can be referred to this genus is not abundant at any period the genus undoubtedly occurred on this continent during the later Tertiary. One record is from deposits as late as the early Pleistocene but this is not based upon positively identified material.

In Europe the records of *Pterocarya* commence with the Oligocene. The Tertiary species are numerous and widespread, the abundant *Pterocarya denticulata* Heer being found from Bohemia and Transylvania through Germany, Switzerland and England northward to western Greenland. This widespread species which continues unabated throughout the Pliocene period is thought to be the direct ancestor of the existing *Pterocarya caucasica.* There are at least five additional Miocene species.

The Pliocene species are numerous and abundant and are found all over southern Europe being especially common along the elevated shores of the extended Mediterranean sea, in the plateau region of central France, and in the Appenines of Italy. The still existing *Pterocarya caucasica* makes its appearance in the plateau region of central France at this time where it is represented by both leaves and the characteristic fruits. It still grew in Netherlands in the early Pleistocene according to Dubois, but was apparently exterminated during the glacial period. It is also known from the Altai Mountains of central Asia in deposits of this age. In figure 4 the known range of the fossil species is shown by vertical lining. It seems obvious from the distribution of the ancestral forms and the very circumscribed range of the few living descendents that the genus is approaching extinction.

THE GENUS PLATYCARYA

The genus *Platycarya* was characterized by Siebold and Zuccarini, who have described so many oriental plants. It is a monotypic genus, that is to say, it contains a single existing species, which was the basis of the genus *Fortunaea* of Lindley. This single species is a small tree of Japan and northern China and its range is roughly shown on the accompanying map (fig. 4) in solid black. Monotypic genera usually have a very interesting geological history, as for example *Sassafras, Comptonia, Ginkgo,* and many others. However, no fossil remains of *Playtcarya* have been discovered and this is probably due to the fact that the vast continent of Asia is practically unexplored.

CONCLUSION

Forestry experts warn us that commercial hickory is growing scarce, just as the black walnut is already scarce. Aside from our enjoyment of their fruits and the very special practical ends which the wood fulfills we should not forget the sentiment which attaches to a family of such magnificent trees, a family with an ancestry, as we have just seen, extending back millions of years to a far off time when the dominant animal population of the globe was the uncouth reptiles of the Cretaceous, a time when the evolution of the mammalia had not yet been wrought out and when man was a far distant promise, not even hinted at in the teeming life of that age. While we can never hope to bring back the primeval forests of our ancestors we can use the intelligence which has been so slowly acquired through the ages in conserving these magnificent tree relics of bygone ages.

THE ALTAMAHA GRIT REGION IN DECEMBER

ROLAND M. HARPER
University, Alabama

In December, 1910, the writer had occasion to cross the Altamaha Grit region or middle third of the coastal plain of Georgia from north to south near its center, by a new route, the Georgia and Florida Railway, most of which had been built since the publication of a description of the region about four years before.[1] This railroad, which now has more mileage in the Altamaha Grit region than any other one system, enters the region from the south at Valdosta, traverses it for about 165 miles in a direction averaging a little east of north, and leaves it a few miles north of Swainsboro. Before the date of this narrative the only portions of the main line north of Valdosta that I had traveled on were between Willacoochee and Nashville, 17 miles, and between Hazlehurst and an undetermined point about 20 miles south of there, where the route was changed a few years ago.

On the sixth of the month named I traveled by this route from its southern terminus (in Florida) to Douglas, and two days later from Douglas to Swainsboro. This gave me an opportunity for seeing over 100 miles of new territory, in a month in which I had never been in that region at all before. Although no new facts of exceptional interest were discovered, the following notes on the trip will at least serve to illustrate a simple method of phytogeographical research of which most botanists who travel by rail fail to take advantage, thus throwing away valuable opportunities.

For about the first 50 miles north of Valdosta the country is comparatively level, not quite as much so perhaps as the flat pine-barren region nearer the Atlantic coast, into which it seems to pass by imperceptible gradations, but considerably more so

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[1] Ann. N. Y. Acad. Sci. **17**: 1–414. November, 1906.

than most of the Altamaha Grit region. In this part the streams have cut down very little below the general level, and shallow ponds full of trees are common.

Just south of the Satilla River the railroad—as one travels northward—descends rather suddenly, as if leaving a plateau,[2] and from there to Swainsboro and beyond the topography is mostly what might be called submaturely dissected by normal erosion, except that ponds, which probably have nothing to do with recent erosion, are still seen every few miles at least. Near Douglas some of the valleys of the smallest streams are as much as thirty or forty feet deep. About midway between Douglas and Hazlehurst the country is rather flat and ponds are common again for several miles, presumably representing an interstream area not yet dissected by branches. Along the Altamaha River and within a few miles of Swainsboro the erosion cycle seems to have progressed a little farther than in other parts of the same region, for there some of the valleys show a tendency to depart from the characteristic broad V-shape and become flat-bottomed, and ponds are scarce.

The only muddy river crossed by the Georgia and Florida Railway south of Swainsboro is the Altamaha, which forms the boundary between Toombs and Jeff Davis Counties. The Ohoopee, crossed in Emanuel County, rises in the upper third of the coastal plain, and its water is presumably a little calcareous. The other streams crossed all rise within the Altamaha Grit region, and of these the only ones large enough to be bordered by hammocks and sand-hills are the Allapaha River, separating Berrien and Coffee Counties, the Satilla River and Seventeen-Mile Creek, in Coffee, Tiger Creek, in Toombs, and Pendleton's Creek in Emanuel.[3] (The two last-named creeks are only about two miles apart, with Normantown on the divide between them.)

The soil is rather sandy nearly every mile of the way, but Pliocene loam seems to be within a few feet or inches of the sur-

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[2] In the Altamaha Grit region, unlike the neighboring lime-sink region, flat surfaces, other than river bottoms, seem to be bordered always by valleys, never by hills.

[3] See classification of streams in Ann. N. Y. Acad. Sci. **17**: 28. 1906.

face everywhere except in the sand-hills. Only one natural outcrop of the characteristic pine-bark-colored rock[4] of the region was seen, that on a hillside about two miles south of Vidalia, in Toombs County.[5] Some of the same is exposed in cuts near Hazlehurst.

All along this route the pine timber, where not already destroyed by farmers, has been severely culled by lumber and turpentine men, and only two patches of "round timber" (*i.e.*, that which has not been turpentined) were noticed; one in Berrien County near Bannockburn, and one in Toombs County near Vidalia. Except in the flat country between Douglas and Hazlehurst I was hardly ever more than a mile from a cultivated field; but the ravages of civilization have not yet been great enough to prevent one's seeing more native species of plants in nearly every mile of the journey than can be recorded in the two or three minutes it takes to travel that mile.

The native vegetation is of course on the whole decidedly of the pine-barren type. The principal habitats observed from the train were dry, intermediate and moist pine-barrens, branch, creek and river swamps, cypress ponds, sand-hills and hammocks. The only muddy river-swamps were those of the Altamaha; and hammocks were chiefly confined to the left sides of Seventeen-Mile, Tiger and Pendleton's Creeks, where they are protected from fire by the sand-hill on one side and the swamp on the other.[6] The plants identified on this trip may all be classed as pioneers except those of river-swamps and hammocks.

In the whole distance of 150 miles 78 species of plants were noted, but only about half of these were seen more than once. Those seen three or more times are listed in table A, which is divided into four parts, viz., (1) trees, (2) large shrubs or small trees, (3) shrubs, palms and woody vines, and (4) herbs. In this table all the various habitats are combined. The number

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[4] See Bull. Torr. Bot. Club **32**: 144. 1905; Ann. N. Y. Acad. Sci. **17**: 22–23. 1906.

[5] The existence of a flag station named Petros, about six miles south of Vidalia, may possibly indicate an exposure of Altamaha Grit near there also.

[6] See Bull. Torr. Bot. Club **38**: 524–525. 1911.

prefixed to each species indicated the number of times it was observed (the same species usually being recorded not more than once between any two consecutive mile-posts). The local common names are added for the benefit of persons other than botanists into whose hands this paper may fall. The relative number of woody and herbaceous plants in this list has little significance, for in summer many more herbs and a few more shrubs could have been identified, but perhaps no more trees: certainly no more evergreen trees.

TABLE A

TREES

96 *Pinus palustris*[7] (long-leaf pine)
89 *Pinus Elliottii*[7] (slash pine)
78 *Nyssa biflora* (black gum)
61 *Magnolia glauca*[7] (bay)
49 *Taxodium imbricarium* (pond cypress)
49 *Quercus Catesbaei* (turkey oak)
39 *Pinus serotina*[7] (black pine)
19 *Quercus cinerea* (high-ground willow oak)
13 *Quercus nigra*[8] (water oak)
12 *Liriodendron Tulipifera* (poplar)
11 *Quercus Marylandica* (black-jack oak)
9 *Pinus Taeda*[7] (short-leaf pine)
4 *Liquidambar Styraciflua* (sweet gum)
4 *Quercus laurifolia*[7]
4 *Pinus glabra*[7] (white or spruce pine)
3 *Acer rubrum* (maple)
3 *Taxodium distichum* (river cypress)

LARGE SHRUBS OR SMALL TREES

32 *Cliftonia monophylla*[7] (tyty)
19 *Cyrilla racemiflora*[8] (tyty)
12 *Ilex myrtifolia*[7] (yaupon)
9 *Nyssa Ogeche* (tupelo gum)

SHRUBS, ETC.

43 *Serenoa serrulata*[7] (saw-palmetto)
40 *Ilex glabra*[7] (gallberry)
16 *Smilax laurifolia*[7] (bamboo vine)
12 *Phoradendron flavescens*[7] (mistletoe)
9 *Hypericum fasciculatum*[7]
6 *Quercus pumila* (oak runner)
4 *Myrica pumila*[7] (myrtle)

HERBS

79 *Aristida stricta* (wire grass)
30 *Eupatorium compositifolium*[9] (dog fennel)
29 *Sarracenia flava*[8] (pitcher plant)
24 *Chondrophora nudata*
15 *Tillandsia usneoides*[7] (moss)
13 *Eriogonum tomentosum*
12 *Andropogon Virginicus*
8 *Baptisia perfoliata*
6 *Helianthus Radula*
6 *Kuhnistera pinnata* (summer farewell)
5 *Sarothra gentianoides*[9] (poverty weed)
5 *Andropogon glomeratus*?
4 *Pteridium aquilinum* (fern)
3 *Euthamia* sp.[9]

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[7] Evergreens.

[8] Semi-evergreens.

[9] Seen only in unnatural habitats, and presumably not indigenous to the region.

It is interesting to note that this list contains all the gymnosperms known in the Altamaha Grit region except the two rarest ones (*Pinus echinata* and *Juniperus Virginiana*), and that the first seven trees are the same that I had previously designated[10] as the seven commonest in the region. Also that 12 of what I considered the 14 commonest trees are among the first 15 in the present list, and 13 of them among the first 17. This section through the middle of the Altamaha Grit region is therefore a thoroughly typical one, as might have been expected.

Although the herbage was practically all dead at the time mentioned, more native herbs were identified from the train than one would be likely to recognize in traveling at the same speed for a similar distance through a hardwood region even in midsummer.

To bring out certain differences in local distribution the journey may be divided into three approximately equal parts, namely, from Valdosta to the Satilla River, 54 miles; from the Satilla to the Altamaha, 48 miles; and from the Altamaha to Swainsboro, 48 miles; and the plants of each listed separately. In doing this the trees, shrubs and herbs seen more than once will be combined and arranged simply in order of frequency numbers in each column, and evergreens will not be distinguished. If the typographical difficulty of it did not forbid, the same names in different columns could be connected by lines, to make plainer whatever differences there are between the three lists of table B.

The frequency numbers in the first column, notwithstanding the greater distance covered by it, average somewhat smaller than in the other two, because between Valdosta and Douglas I happened to sit on the side away from the mile-posts, and consequently did not repeat my notes on each species as often as I did on the remainder of the journey.

Making due allowance for the circumstance just mentioned, it will be noticed that *Pinus Elliottii*, *Taxodium imbricarium*, *Ilex myrtifolia*, *Nyssa Ogeche*, *Ilex glabra*, *Serenoa*, *Sarracenia flava*, and *Helianthus Radula* are decidedly more abundant in the southern or coastward or flatter parts of the region, while

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[10] Ann. N. Y. Acad. Sci. **17**: 327, 329. 1906.

TABLE B

25 *Pinus Elliottii*
20 *Taxodium imbricarium*
19 *Ilex glabra*
18 *Pinus palustris*
17 *Sarracenia flava*
16 *Aristida stricta*
14 *Serenoa serrulata*
14 *Magnolia glauca*
13 *Eupatorium compositifolium*[11]
12 *Ilex myrtifolia*
11 *Nyssa biflora*
9 *Cliftonia monophylla*
8 *Pinus serotina*
7 *Quercus Catesbaei*
6 *Chondrophora nudata*
4 *Quercus nigra*
4 *Curilla racemiflora*
4 *Smilax laurifolia*
3 *Quercus cinerea*
3 *Nyssa Ogeche*
3 *Helianthus Radula*
3 *Tillandsia usneoides*
2 *Phoradendron flavescens*

38 *Pinus palustris*
36 *Aristida stricta*
33 *Nyssa biflora*
32 *Pinus Elliottii*
27 *Serenoa serrulata*
24 *Taxodium imbricarium*
21 *Magnolia glauca*
21 *Pinus serotina*
21 *Quercus Catesbaei*
16 *Chondrophora nudata*
16 *Cliftonia monophylla*
12 *Ilex glabra*
9 *Sarracenia flava*
8 *Quercus cinerea*
8 *Tillandsia usneoides*
6 *Nyssa Ogeche*
6 *Quercus Marylandica*
6 *Andropogon Virginicus*
5 *Quercus pumila*
5 *Smilax laurifolia*
5 *Eriogonum tomentosum*
5 *Eupatorium compositifolium*[11]
4 *Liriodendron Tulipifera*
4 *Pinus Taeda*
3 *Liquidambar Styraciflua*
3 *Cyrilla racemiflora*
3 *Phoradendron flavescens*
2 *Eriocaulon decangulare*
2 *Acer rubrum*
2 *Quercus nigra*
2 *Helianthus Radula*
2 *Euthamia* sp.[11]
2 *Sarothra gentianoides*[11]

40 *Pinus palustris*
34 *Nyssa biflora*
32 *Pinus Elliottii*
27 *Aristida stricta*
26 *Magnolia glauca*
21 *Quercus Catesbaei*
13 *Eupatorium compositifolium*[11]
12 *Cyrilla racemiflora*
10 *Pinus serotina*
9 *Ilex glabra*
8 *Quercus cinerea*
8 *Liriodendron Tulipifera*
8 *Baptisia perfoliata*
7 *Quercus nigra*
7 *Cliftonia monophylla*
7 *Smilax laurifolia*
7 *Phoradendron flavescens*
7 *Hypericum fasciculatum*
7 *Eriogonum tomentosum*
6 *Andropogon Virginicus*
5 *Taxodium imbricarium*
5 *Quercus Marylandica*
5 *Kuhnistera pinnata*
4 *Myrica pumila*
4 *Pteridium aquilinum*
4 *Andropogon glomeratus?*
4 *Tillandsia usneoides*
3 *Sarracenia flava*
3 *Pinus glabra*
2 *Chondrophora nudata*
2 *Quercus laurifolia*
2 *Taxodium distichum*
2 *Osmanthus Americana*
2 *Serenoa serrulata*
2 *Sarothra gentianoides*[11]

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[11] Seen only in unnatural habitats, and presumably not indigenous to the region.

Pinus palustris, Quercus Catesbaei, Q. cinerea, Q. Marylandica, Liriodendron, Pinus Taeda, P. glabra, Quercus laurifolia, Taxodium distichum, Osmanthus, Cyrilla, Phoradendron, Hypericum fasciculatum, Myrica pumila, Aristida stricta, Andropogon Virginicus, Eriogonum, Baptisia perfoliata, Kuhnistera and *Pteridium* are more abundant in the northern or more hilly parts. It is significant that the species in the former category mostly inhabit bogs, shallow ponds, or flat pine-barrens, while those in the latter prefer dry pine-barrens, sand-hills, hammocks, river-swamps, etc., where the seasonal fluctuations of ground-water are greater, thus providing a deeper zone in which the various soil-forming agencies can work, and making a richer or at least less sour soil.

The following notes on the distribution of certain species may be of some service to future explorers of this interesting region.

Pinus Taeda L. On this route almost confined to the bottoms of the Altamaha and Ohoopee Rivers and Pendleton's Creek.

Pinus glabra Walt. In the hammocks of Seventeen-Mile, Tiger and Pendleton's Creeks and the Ohoopee River.

Taxodium distichum (L) Rich. Seen only in the bottoms of the two rivers which rise north of the Altamaha Grit region, namely, the Altamaha and the Ohoopee.

Taxodium imbricarium (Nutt.) Harper. Common in shallow ponds south of the Altamaha River, rare north of there.

Arundinaria tecta (Walt.) Muhl. Seen only in a branch-swamp just north of Huffer, or six miles north of Douglas, Coffee County. More common in regions where the vegetation is on the whole a little nearer the climax condition.

Serenoa serrulata (Mx.) B. & H. Rather common in flat pine-barrens and related habitats, south of the Altamaha. Last seen about six miles north of that river.

Quercus Marylandica Muench. First seen in dry pine-barrens about two miles south of Hazlehurst or twelve miles from the Altamaha River. More frequent northward.

Quercus nigra L. On this route almost confined to river-bottoms.

Magnolia grandiflora L. Seen only in the sandy hammocks of Seventeen-Mile and Tiger Creeks. Associated at both places with *Pinus glabra* and *Quercus laurifolia*, as is very often the case.

Sarracenia flava L. This species, which is very rare in the typical flat pine-barrens of Southeast Georgia and adjacent Florida, was first noticed between Allenville and Nashville, Berrien County. It is frequent from there to Douglas, but was not seen often north of the Altamaha River, where its favorite habitat, sloping moist pine-barrens, is scarcer.

Liquidambar Styraciflua L. Noticed only in the Altamaha River bottoms; but in summer it would doubtless have been seen oftener.

Baptisia perfoliata (L.) R. Br. First seen about 2 miles north of the Altamaha River, which is pretty near its southwestern limit.

Cliftonia monophylla (Lam.) Sarg. Frequent in the central part of the region, in small sour swamps whose water stands at very nearly the same level throughout the year. Not seen between the Altamaha and Ohoopee Rivers, a distance of about 35 miles.

Ilex myrtifolia Walt. Abundant in shallow ponds in Berrien County, as noted in former years.[12] Not seen north of the Satilla River this time.

Nyssa Ogeche Marsh. Abundant in the Satilla River and several creeks, but not seen north of the Altamaha. This curious little tree seems to be confined to bodies of water, either stagnant or flowing, whose level fluctuates not less than 2 nor more than 6 feet in the course of the year.

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[12] See Ann. N. Y. Acad. Sci. **17**: 207–208. 1906; Southern Woodlands **1**^{4}: 15–16. 1907.

BOOKS AND CURRENT LITERATURE

Cytology of Rhodochytrium.—Several years ago in a preliminary paper, Atkinson reported the presence in North Carolina of *Rhodochytrium spilanthidis* Lagerh. on the ragweed, *Ambrosia artemisiaefolia.* This remarkable parasite was discovered in 1889 near Quito, Ecuador, on a species of *Spilanthes.* A peculiar interest centers around this form because of the transitional position which it occupies in our phylogenetic scheme. It shows a relationship on the one hand to certain protococcoid algae, as *Phyllobium,* and on the other to some of the chytridiaceous fungi, as *Synchytrium.*

Griggs[1] has recently published a highly interesting as well as exhaustive consideration of the life history and cytology of a *Rhodochytrium.* The retort-shaped cysts appear as bright red specks within the tissue of the leaves and stems of ragweed. Rhizoids, basal and lateral, extend into the vascular tissue especially the phloem elements. The cysts, which are formed during May and June, become zoosporangia, producing zoospores of the algal type. The zoospores rarely conjugate except when confined to small amounts of fluid. Those which come to rest upon the host form germ tubes, which can penetrate the tissues at any point. As a result of the infections, other temporary sporangia are formed or, if it is later in the season, July or August, resting sporangia are developed instead. These resting sporangia differ from the temporary sporangia in that their walls are thicker and they remain dormant till the following season. The walls of the resting sporangia consist of three layers, the outer of which is formed first. The two outer layers, which are composed of cellulose, constitute the exospore, while the endospore consists of a layer of non-cellulose material.

Owing to the fact that *Rhodochytrium* has no chlorophyll, special consideration is given to starch formation. The starch grains, so far as could be determined, are formed in the cytoplasm without the intervention of plastids, pyrenoids or other specialized protoplasmic bodies. There is no evidence, even, of the presence of microsomes as found by

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[1] Griggs, R. F., The Development and Cytology of *Rhodochytrium.* Bot. Gaz. **53**: 127-173. pls. 11-16, 1912.

Strasburger in *Marsilea* and *Pinus.* Cytological evidence shows that it bears a close resemblance in many points to *Synchytrium.* The question of species on the different hosts and the theoretical aspect of relationship to other thallophytes is treated in a very conservative manner.—FREDERICK A. WOLF.

THE LIFE OF THE PLANT.—More interesting to the general reader than to the trained botanist The Life of the Plant, by the eminent Russian plant-physiologist Timiriazeff, is curiously uneven in merit.[1] The lectures, of which this volume is one fruit, were begun in 1870, and the English translation by Miss Chérémétcff is from the seventh Russian edition. As lectures, skillfully illustrated by ingenious experiments they must be fascinating to hear. As a treatise on plant-physiology they are disappointing. Remarkably clear in the description of phenomena and in the discussion of the causes and means of some of these, they do not satisfy. For the most part the explanations are correct, but they do not penetrate even that short distance below the surface which is now attainable. Extolling the work of Darwin but making no mention of DeVries, silent about the studies of others on the problems of breeding and heredity except for petulant allusions to some fellow Russian botanists, we are taken back twenty years or more, when reflection and fancy rather than the results of experiment formed the bulk of evolutionary thought and publication. One would be glad to see the results of the application, during the last two decades, of chemistry, physics, and physical-chemistry to those phenomena of life which we can reach at all, the phenomena of nutrition, respiration, growth, and reproduction, more fully appreciated and acknowledged. On the other hand, it should be axiomatic that a physiologist should know anatomy; but a treatise on The Life of the Plant should be possible without extensive anatomical and morphological descriptions. To be sure, anatomy is regarded in too many American botanical schools as "dry bones" or is omitted altogether. Perhaps, therefore, the descriptions of seed, root, leaf, and wood anatomy are necessary: but they ought not to be. The book is well printed and bound, but unfortunately it is more attractive than satisfying.—G. J. P.

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[1] Timiriazeff, K. A., The Life of the Plant. London, Longmans Green & Company, 1912. ($2.50.)

The Rôle of Secondary Pigments.—In a preliminary paper A. V. Richter[1] announces some important conclusions as to the part played by coloring matters other than chlorophyll in the process of photosynthesis. He states that the interpretation of Engelmann as to the rôle of secondary pigments is incorrect. These pigments, as, for instance, phycoerythrin, play no active part in photosynthesis. Apparently he includes in this statement the possible action of such substances in affecting the region of the spectrum in which absorption takes place. In short then, according to Richter, the energy of absorption and assimilation are not equal in such plants as the red, brown, and blue green algae. When the complete results have been published it will no doubt be easier to follow his conclusions.—H. M. R.

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[1] Richter, A. V., Farbe und Assimilation. Ber. d. Deutschen Bot. Gesell. Bd. 30: 280–290, 1912.

NOTES AND COMMENT

Dr. H. C. Cowles, of the University of Chicago, is organizing an International Phytogeographical Excursion to visit the United States in the late summer of 1913. A number of European plant geographers have already signified their intention of joining the excursion, including several of the men who accompanied the tour of the British Isles in 1911. The Transcontinental Excursion of the American Geographical Society, which is now traversing the United States, includes among its number two well known botanists, Dr. Gunnar Andersson, of the University of Stockholm, and Wladimir Dubianskij, of the Imperial Botanical Garden, St. Petersburg. Such international excursions are becoming very frequent and popular, and those to which we allude will do much to stimulate interest in the natural features of the United States.

We are glad to see that the editors of the series of Monographs on Biochemistry, which is being published by Longmans, Green and Company, are construing their subject in the broadest possible manner. The last volume to appear is on Soil Conditions and Plant Growth, from the hand of Dr. Edward J. Russell, of the Rothamstead Experimental Station. The entire series is well worthy of the attention of botanists, including such subjects as The Nature of Enzyme Action, The Vegetable Proteins, Colloids, etc.

A very sane and practical course of nature study work has been outlined by Mrs. Gregson, an Englishwoman, in her small book The Story of Our Trees (Cambridge University Press). A series of twenty-four lessons, following the course of the school year, is devoted to suggestions for elementary work on the lines which form the basis for scientific forestry. British materials are used, of course, throughout the book, but it would be easy for American teachers to select native forms to illustrate a similar course.

EFFECT OF SOLANINE ON THE POTATO PLANT[1]

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In connection with the investigation of the unproductivity of some potato soils, the effect of solanine on the growth of potatoes was studied. Solanine is a constituent of the potato vine and occurs in appreciable quantities in young potato sprouts. In as much as solanine is a constituent of potatoes, it is interesting to note its effect on growth when presented to the plant.

Otto and Kooper,[2] also Albo,[3] showed that nicotine, which is a constituent of the tobacco plant, was beneficial to the growth of tobacco. These experiments were made by adding nicotine to culture solutions in which the plant was growing.

Lutz[4] has shown that atropine, which is a constituent of Atropa belladona, is harmful to the growth of that plant. His experiments were made by adding atropine to sand in which the plant was growing.

The experiments conducted to test the effect of solanine on the growth of potatoes were made by growing the potato plants in aqueous solutions. The potatoes were sprouted on perforated aluminum disks floated on the surface of a pan of water by means of cork or rubber floats. When the sprouts were about two inches high the mother potato was removed from the plant, leaving the roots and top intact, thus forcing the seedling to live upon the culture media furnished. The young plants were then supported

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[1] From the laboratory of Soil Fertility Investigations, by permission of the Secretary of Agriculture.

[2] Otto, R. and Kooper, W. D. The influence of poisonous alkaloid solutions on soil and plants. Landw. Jahrb., **39**, 397 (1910).

[3] Albo, G. The physiological rôle of nicotine in the tobacco plant. Contrib. Biol. Veg. Roy. Ist. Bot., Palerno, **3**, 69. 1902.

[4] Lutz, M. L. Rechèrches sur la nutrition des végétaux a l'aide de substances azotéés de nature organique (aminis sels d'ammonium composés et alcaloides.) Thèse, Paris, (1898); Ann. Sci. Nat. Bot. (8), **7**, 1. 1899.

THE PLANT WORLD, VOL. 15, NO. 11, NOVEMBER, 1912

in corks and put in the culture bottles, one plant to each bottle, containing 250 cc. of solution. The culture method and manner of securing uniform plants was similar to that described in an earlier volume of this journal.[5]

Solanine being almost insoluble, could be used in only one concentration, namely, a saturated solution. Purified distilled water was used as the culture solution in the first experiments. Four cultures of distilled water as a control and four of water containing the solanine were started March 9 and continued until April 5, when the green weight was taken and recorded. The culture solutions were changed every three days during the experiment. The green weight of the four cultures in distilled water was 8 grams and the weight of the four cultures containing solanine was 6.6 grams. From this it appeared that there was a slight harmful effect from the solanine. This test, as stated above, was made in distilled water in which the solanine is very difficultly soluble only to the extent of a few parts per million in cold water.

Other experiments were next made in which the water was boiled to aid in getting the solanine in solution. Three cultures of distilled water as a control and three of the water containing solanine were used. Both the control and the solanine solutions were boiled and after cooling were aerated. The solanine was more soluble in the hot water, so that a saturated solution could be made, which, however, still contained less than fifty parts per million. The plants grew from June 13 to July 1. The solutions, as before, were changed every three days. Two of the solanine plants were killed in this experiment and the one that survived at the end of eighteen days weighed only 0.26 grams while the three control plants in the distilled water weighed 1.84 grams. It is apparent that in these distilled water cultures the solanine had a detrimental effect on the growth of the potato plant.

The effect of solanine on growth was also tested by using potato soil extracts as culture solutions. The extract of a good soil and a poor soil was used in this test. To obtain any appreciable amount of solanine in solution, the extract had to be boiled as

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[5] Skinner, J. J. Water Culture Method For Experimenting With Potatoes. Plant World 2, 249. 1908.

before, and then allowed to cool and aerate. The control in soil extract as nutrient solution, was heated in the same manner so as to have all conditions alike except the presence of solanine. For each treatment three cultures were grown. The plants were put in fresh solution every three days. The experiment was conducted from October 7 to November 10. The treatment and green weights are given in Table 1.

Fig. 1. Showing the harmful effect of Solanine on potato plants. *1*, Soil extract with Solanine; *2*, Soil extract without Solanine.

The solanine proved to be harmful in each of these tests. With the good soil extract as the nutrient solution the growth was reduced from 6.82 grams to 2. 33 grams, a decrease of 66 per cent, and with the poor soil extract from 4.60 to 1.83 grams, a reduction of 60 per cent. The growth in the good soil extract with and without solanine is shown in figure 1.

In another experiment conducted at a different time essentially the same results were obtained. The solanine again being dissolved by heating as before. The plants grew from June 13 to July 15. The solutions were changed as before, every three days. The weights of the three plants in the soil extract control was 2.72 and the corresponding solanine cultures were 1.98 grams. The soil extract from another soil gave 2.88 grams and the corresponding solanine cultures 1.35 grams. In this experiment as well as the others given in this paper, the roots of the plants were also injured by the solanine. The roots in the solanine cultures did not develop and branch as they did in the control cultures.

TABLE 1.

Effect of solanine on the growth of potatoes.

	Green weight of 3 cultures. *Grams.*
Extract of good potato soil, boiled,	6.82
Extract of good potato soil, boiled + solanine	2.33
Extract of poor potato soil, boiled,	4.60
Extract of poor potato soil, boiled + solanine	1.83

Although solanine is a constituent of potatoes, it is apparent from these experiments, in which distilled water and soil extract were used as the culture solutions, that it is harmful to the growth of the potato plant, when presented in a culture solution.

THE ORIGIN AND DEVELOPMENT OF THE BINOMIAL SYSTEM OF NOMENCLATURE

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Despite the importance of binomial nomenclature in modern biology, no careful study appears to have been made, or at least published, as to its origin and development into the present form. Such references to the subject as do exist are of a very general character and are frequently erroneous, following one or the other of two opposing views. The most commonly accepted opinion is that to Linnaeus alone should credit be given for establishing this system, while others hold such a position as that of Sachs[1] and see in Linnaeus' work no original contribution to the development of the system, but merely the firm establishment of methods already in use. That either of two such divergent views should alone be correct is shown by experience to be inherently improbable, and a careful study of the evidence shows in fact that the truth does lie between these two extremes.

As might be expected, there was little or no recognized system followed in the very earliest plant nomenclature. Where but one plant of a kind was known, usually a single name was sufficient, *e.g.*, *Clethra;* where two or more of a kind were known, an additional word or phrase was added to the name already given to distinguish the different kinds, *e.g.*, *Mespilos anthedon*, precisely as in our own popular terminology, we say Chestnut, but Red Oak, Pin Oak, etc. In such cases the first name was such as we would now regard as generic, while the second word or phrase was specific; and both the generic and the specific parts might consist either of one or more words, although naturally, as the number of known species increased, many of the specific names developed into long descriptive phrases. In this way a

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[1] Sachs, J., History of Botany. Translated by Garnsey and Balfour, Oxford, pp. 33 and 83, 1906.

binary system of nomenclature, that is, one in which a plant received two distinct designations, a generic and a specific, gradually evolved, varying in form from the concise names used by Brunfels, where a single word commonly served for a specific name, to the wordy phrases of later authors. In 1623 appeared a work epoch-making in biological nomenclature—Caspar Bauhin's Pinax Theatri Botanici, an exhaustive synonymy of all the species of plants then known. But of chief importance from our point of view is the fact that here the binary system of nomenclature is definitely recognized and consistently followed. No new features were introduced, but the complete and authoritative character of the book was such as to gain general acceptance of the methods therein adopted. This point Sachs emphasizes, and claims that for this reason as much, if not more, credit should be given to Bauhin as to Linnaeus, who, says Sachs, merely adopted this system of Bauhin's and established its universal use by his employment of it in his extensive systematic studies which were of world wide influence. Greene[2] in his admirable Landmarks of Botanical History, as well as in personal communications, for which, with much other helpful counsel, I am most greatly indebted to him, expresses substantially the same view. This is the basis for the second of the aforementioned two views held today, but its supporters fail to recognize any difference between our modern binomial system in the formation of which Linnaeus had so large a part, where both the generic and specific name are intentionally limited to one word, and this binary system culminating in the work of Bauhin, the main points of which may be summarized as follows: (1) Every plant received both a generic and a specific name; (2) The generic name might consist of more than one word; (3) The specific name might consist of several words constituting a descriptive phrase; (4) The generic and specific name might each consist of a single word, thus making the name binomial. Such binomials, however, it must be remembered, were purely accidental and represented no definite system.

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[2] Greene, Edw. L., Landmarks of Botanical History. Smithsonian Miscellaneous Collections, p. 31, 1909.

A second step toward a binomial system of nomenclature was taken by Bachmann[3] better known as Rivinus. In his Introductio Universalis in Rem Herbariam (1693) he discusses the subject of plant names, and distinctly recommends a binomial system saying "Ast si semel quoddam eorum electum fuerit tanquam genericum, e. gr. Horminum, tunc levissimo artificio superaddi potest nota specificae differentiae per modum cognominis." (But if anyone of these shall be once selected as the generic [name] as Horminum, then by a very easy device a notice of the specific difference can be given also by the character of the second name). This method of nomenclature seemed to Rivinus advisable because of the difficulty of using the long and cumbersome names which had resulted from the great increase in the number of species known, *e.g., Convolvulus perennis heteroclitus, floribus herbaceis, capsulis foliaceis, strobili instar.* Especially, in his opinion, would a more concise method be advantageous in the names of medicinal plants used by apothecaries. Bachmann, therefore, clearly saw the advantages of a binomial nomenclature, and had he followed his own precepts consistently doubtless he and not Linnaeus would have been regarded as the founder of the binomial system.

That Linnaeus was familiar with the works of his predecessors is well known, and shown by references thereto in his writings. Following directly in the steps of Bauhin, he adopted and consistently used, in his earlier works at least, a binary system in which however the generic name was commonly limited to a single word, while the specific name might or might not be one word, and in the majority of cases consisted of a descriptive phrase. Such names, however, he evidently found cumbersome, and we are fortunate, indeed, in being able to trace the steps whereby he was led to the use of a more concise binomial system. According to Professor Fries[4] such a system was first devised by Linnaeus as a means of assisting his students, who, confused by existing methods of plant nomenclature, desired some more simple method. However this may be, the earliest printed evi-

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[3] Bachmann, A. Q., Introductio Universalis in Rem Herbariam, p. 11.

[4] Quoted by Olsson-Seffer, Jour. of Botany, Sept., 1904.

dence of the introduction of such a system is found in the indexes of certain volumes of travel by Linnaeus, to which my attention has been called by B. Daydon Jackson, who has most kindly sent me many valuable suggestions upon the subject These are the Öländska och Gothländska Resa, 1745, and Wästgötha Resa, 1747. In the index to the earliest of these we find such names as *Juncus sylvaticus, J. Bufonius, Rumex Lapathum, R. Britannica,* etc., some of which are recognized as the present names of species, and it is quite probable that such short forms were used orginally merely as a matter of convenience in indexing.

A far more important step in the evolution of his binomial system was the appearance in 1749 of the Pan Suecus, a paper issued in the Amoenitates Academicae, written not by Linnaeus, but by one of his pupils under his direction. In spite of its very great value this paper appears to have received heretofore very little attention in its relation to this subject, and on this account I have made a careful study of it with particular reference to the nomenclature used therein. The article, primarily describing a series of experiments carried on for the purpose of determining which of the native Swedish plants were eaten by certain domestic animals, contains a list of plants which for our purpose is the only important part of the article, for in this list a binomial system is adopted and practically consistently carried out.

The list contains the names of 866 plants (856 consecutively numbered as in the Flora Suecica, 2 additional numbers, 8 unnumbered); 22 of these have to be disregarded, mainly because they cannot be definitely identified, leaving a working list of 844. Of these 754 or 90 per cent are binomials, *e.g:* Salicornia maritima, Hippuris aquatica, Callitriche palustris, Ligustrum vulgare. In form these names are apparently identical with the binomials used by Bauhin and also with those employed to-day. So far as concerns the first word, which is generic, this is true. But in respect to the second word there is this essential difference, that whereas in Bauhin and in modern nomenclature this second word is a true specific name consisting of a single word (single by chance in the former case, and by intention in the latter), it is in the Pan Suecus in no sense a specific name but a special concise designation termed a *trivial* or *vulgar* name, adopted by Linnaeus to be used for convenience in place of the long unwieldy descriptive phrase which was still retained as the old specific name.

In the Philosophia Botanica which appeared two years later Linnaeus says:[5] "Nomina Trivialia forte admitti possunt modo, quo in Pane suecico usus sum; constarent haec

Vocabulo unico:

Vocabulo libere undequaque desumto.

Ratione hac praecipue evicti, quod differentia saepe longa evadit, ut non ubique commode usurpeturdein mutationi obnoxia, novis detectis speciebus" ("trivial names may be used as I have used them in the Pan Suecus. These consist of a single word chosen from any source whatever. We are convinced of the value of this because descriptions of specific differences often become very long so that they cannot be conveniently used eveywhere, and are subject to change if new species are discovered.")

As these trivial names are a wholly new feature in nomenclature and Linnaeus' principal contribution thereto, it is of interest to consider their relations to the specific name in each case and if possible to determine the source from which Linnaeus took them. This can readily be done owing to the fact that the names in the list in the Pan Suecus are numbered identically with the same plants in the Flora Suecica, where not only the specific name attributed to the plant by Linnaeus is given, but also synonymous names of other botanists. A careful study of the entire list shows that Linnaeus drew these trivial names from four sources as follows: (1) Generic names used by earlier botanists, 118—13.9 per cent; (2) Adopted from specific name, 365—43.2 per cent; (3) Composed from words used in specific name, 49—5.8 per cent; (4) Entirely new words, 312—36.9 per cent. Although Linnaeus says that the trivial names may be chosen from any source whatever, thus allowing for the use of purely arbitrary names, which later came to be frequently employed,

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[5] Linnaeus, C., Philosophia Botanica, Stockholm, p. 202, 1751.

the classification given above shows that in nearly two thirds of the cases the names are words which were in some way associated with the plant, and with the exception of the first group, practically every name is descriptive.

Such a list would doubtless have had great influence on nomenclature, but the appearance in 1753 of the Species Plantarum, in which every species received a trivial name, definitely determined the method of future nomenclature. It is interesting to note that of the 844 trivial names used in the Pan Suecus Linnaeus retained in the Species only 322, substituting for the remaining 522 names others, selected however from the same sources as in the Pan Suecus and representing his final improvement of the system in detail. These trivial names were placed in the margin opposite the specific names, as Linnaeus says in the preface[6] "Trivialia nomina in margine apposui, ut missis ambagibus, uno quamlibet Herbam nomine complecti queamus." ("I have placed the trivial names at one side in the margin in order that, freed from ambiguity we may be able to distinguish any plant whatsoever by a single name"), and in his own diary we find[7] "Nomina trivialia woro förut ohörde. Linnaeus införde dem öfverallt. Det war detsamme som att sätta kläpp i klocka. Twå namn kunna lätt minnas, lätt nämnas och skrifvas, långt bättre än som förut skedde, långa definitioner." ("Nomina trivialia were before unheard of. Linnaeus introduced them everywhere. It was like putting a clapper in a bell. Two names are easy to remember, easy to pronounce and write, much better than was done before—long definitions.")

It must be noted hower that Linnaeus did not consistently follow his own principles and some trivial names composed of two words occur even in the Species Plantarum. The advantage of this concise form of name was soon recognized and these trivial names were adopted and are now universally used as specific names, displacing the older descriptive phrases, which survive however in the modern synoptical descriptions commonly called diagnoses. Here then we have a binomial system, deliberately

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[6] Linnaeus, C., Species Plantarum, Stockholm, Int, 1753.

[7] Quoted by Olsson-Seffer, Jour. of Botany, Sept. 1904.

planned and for this reason essentially different from the accidental binomials of the earlier binary system. Since the time of Linnaeus practically no change has taken place in our method of nomenclature, and his system is used today, refined only in technical details. Our system, therefore, represents not the creation of one man but a gradual evolution marked by the four main steps here outlined, of which steps Linnaeus took the most important.

1. The development of a binary system culminating in the work of Bauhin.
2. The definite recommendation by Bachmann that the system be binomial.
3. The introduction by Linnaeus of a binomial system through the use of trivial names.
4. The universal adoption of these trivial names as specific names, and the establishment of our modern binomial system.

It is quite conceivable that a binomial system of nomenclature such as is now employed might easily have arisen as the result of the first two steps here outlined had the recommendation of Bachmann been supported by some botanist of preëminent influence. Such however was not the case, and our modern binomial nomenclature in fact owes its most characteristic feature directly to the introduction by Linnaeus of the trivial names, as I trust this study of the historical development of the system sufficiently shows.

THE PHYLOGENY OF GRASSES[1]

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The purpose of this paper is to give a brief discussion of the origin of grasses, and also to consider the essential differences between the tribes of grasses and their probable derivation from a common ancestral type. Grasses have come from the lilies or from lily-like plants by a reduction in the number of the parts of the flower. From the fact that grasses differ from the lilies in just those characteristics which make them more likely to survive the attacks of voracious animals, it may be that the stress of being fed upon has been an important factor in the evolution of the grasses.

In order that we may understand the changes that have taken place in the lilies to produce the grasses, let us consider the structure of a typical lily. Perhaps the Easter lily is the most familiar example. Here we find apparently six white petals but we know that the outer three are sepals. We notice also that there are six stamens in two whorls of three each, and a three lobed or tricarpellary pistil. The first step was a reduction in the lobes of the pistil by causing them to become smaller, functionless, and finally to disappear. Along with this reduction in the lobes of the pistil came a greater and greater tendency to take on the grassy habit of growth. A modification of the perianth also took place. As we pass through the rushes the perianth becomes more "chaffy" and at last is reduced to mere bristles, although in some of the rushes we find that one whorl has disappeared and that the pistil no longer has three lobes. These modifications in addition to a grassy appearance seem to indicate that these rushes (the Eriocaulaceae) are intermediate between the lilies and the grasses. The first grasses were probably all species of the same genus—a primitive group, probably

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[1] Published by permission of the Secretary of Agriculture.

very similar to the bamboos as we know them today. But in any outline of phylogeny, when we state that one form has given rise to another, we do not mean that that form as it now exists has given rise to the other, but that it is the descendent of that progenitor. And so it must be borne in mind that our bamboos did not produce all other grasses, but that they are the modern survivors of a primitive tribe that did give rise, directly or indirectly, to all other tribes of grasses.

The Bambuseae, although woody and often attaining a height of over a hundred feet, are true grasses. Like other grasses their stems are solid at the joints, and live only until flowers are produced. Bamboos do not form flowers in one year, but when they do, like all true grasses, they die down to their perennial roots.

We find in the bamboos, which are undoubtedly the primitive type of grass, the flower structure which is more or less characteristic of all the grasses. Here the perianth has been reduced until only one whorl of greatly reduced scales, called lodicules, remains. The stamens are, in the higher bamboos, reduced to three; one whorl having disappeared. The pistil tricarpellary in the lily, here has but one chamber, although it still retains two or three branches at the top, showing its origin from a three lobed type. The axis bearing the flower has become so short that all that remains are the two bracts or scales (glumes) into which the flower has retreated. These scales in the ancestral type functioned as leaves. The flowers in the primitive grasses were arranged in spikelets or tiny spikes and this structure or a modification of it is characteristic of all the grasses.

Having reached the Bambuseae, which are primitive, let us consider the probable derivation of the other tribes. In the Gramineae the direction of evolution has been a reduction in the number of flowers in the spikelet. Those grasses, then, with relatively more flowers in the spikelet are to be regarded as lower forms, and those with a reduced number of flowers in the spikelet as higher forms. It must follow then that those tribes which are characterized by having but one flower in the spikelet have developed furthest from the original type—the Bambuseae.

The Bambuseae, according to the Besseyan classification,[2] have given rise to three lines of development beginning respectively, with the Festuceae, the Phalarideae and the Andropogoneae. These three lines of development, which for convenience we will designate as the Festucean Line, the Phalaridean Line, and the Andropogonean Line, have given rise to the other tribes, as indicated in the accompanying figure, which also shows a diagrammatic sketch of the spikelet, the inflorescence, and the flower of one genus in each tribe. Following is a list of the genera which have been selected to typify each tribe:

GENUS	COMMON NAME	TRIBE
Bambusa....................	Bamboo	Bambuseae
Bromus....................	Brome Grass	Festuceae
Calamagrostis..............	Reed Grass	Agrostideae
Avena....................	Oats	Aveneae
Lolium....................	Rye Grass	Hordeae
Bulbilis....................	Buffalo Grass	Chlorideae
Phalaris....................	Canary Grass	Phalarideae
Panicum....................	Millet	Paniceae
Oryza....................	Rice	Oryzeae
Andropogon................	Blue Stem	Andropogoneae
Zea....................	Corn	Maydeae.

THE FESTUCEAN LINE

The Festucean Line is characterized by having spikelets with larger flowers at the base while in the other two lines the spikelets are with larger flowers at the top.

Beginning with the Festuceae, we find grasses with from two to many flowers in a spikelet, awnless or with a terminal awn, and with inflorescence a panicle or sometimes a raceme.

The Agrostideae have come in a direct line from the Festuceae by a reduction of the number of flowers in the spikelet to one. Sometimes, as we have illustrated in *Calamagrostis*, a small stalk or rachilla is found which is to be regarded as a vestige of a sec-

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[2] I wish to acknowledge my indebtedness to Dr. Charles E. Bessey, University of Nebraska, whose lectures in systematic botany have been of great assistance in the preparation of this paper.

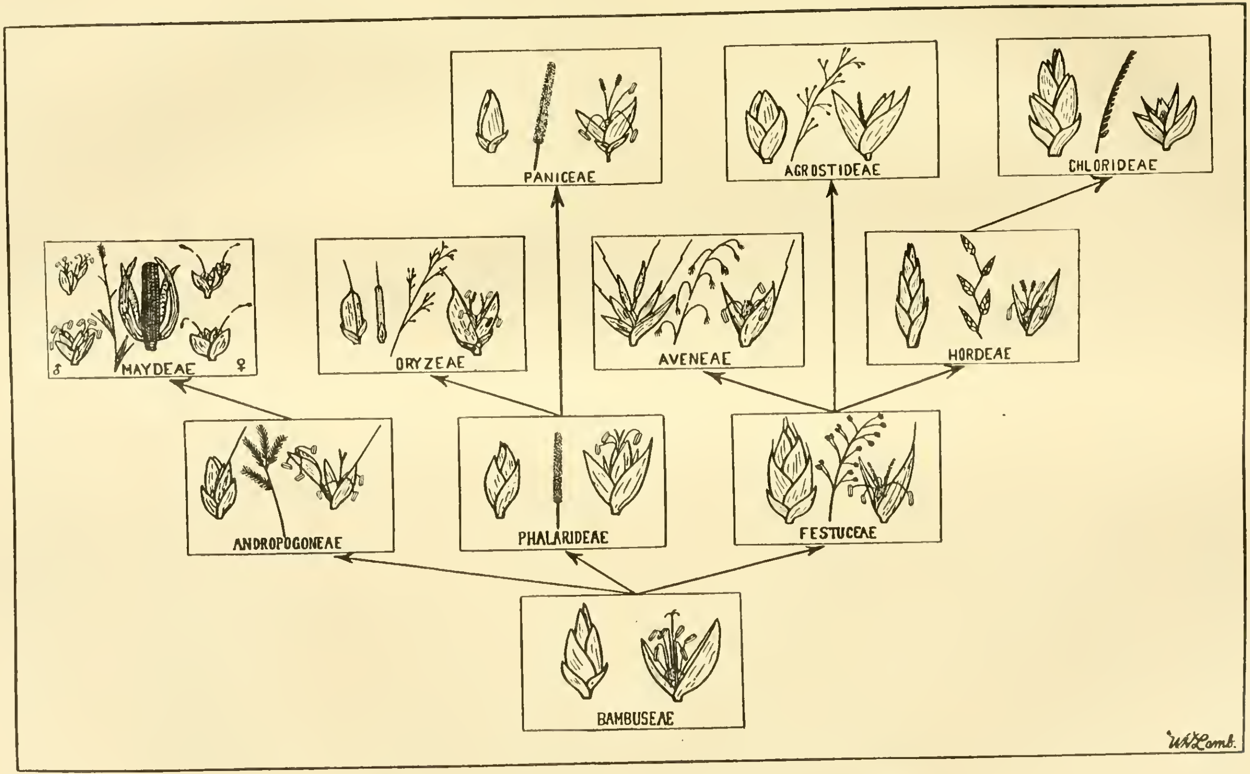

Chart showing the relationship of the tribes of grasses ond flower. In other genera of this tribe, as *Agrostis* (Red Top), this rachilla is wanting.

The Aveneae have come as a side line from the Festuceae by a modification of the position of the awn. In the Festuceae the awn when present is always terminal, but in the Aveneae it is always dorsal.

By a modification of the inflorescence another side line[3] has arisen from the Festuceae which has produced two tribes, the Hordeae and the Chlorideae. The Hordeae, which include such grasses as wheat, barley and rye, were produced by a shortening up of the panicle or the raceme of the Festuceae into a spike—the spikelets being sessile in two rows, one on each side of the main stem or rachis. The Chlorideae have come from the Hordeae by further modification of the inflorescence. In this tribe the sessile spikelets are arranged in two rows, but both rows are on the same side of the rachis, giving the spike the appearance of having a single row of spikelets.

THE PHALARIDEAN LINE

The Phalaridean Line, characterized by having spikelets with larger flowers at the top, has produced the Phalarideae, the Paniceae, and the Oryzeae. The Phalarideae are distinct in that the spikelet, which is jointed above the empty glumes or scales, has only one perfect flower which is contained in the fifth glume or scale. The four empty glumes are to be regarded as vestiges of flowers which have been eliminated in the reduction of the spikelet.

The Paniceae have arisen by a direct line from the Phalarideae by a reduction of the spikelet. A joint is found below the empty glumes instead of above as in the Phalarideae. As representative of the Paniceae the millets are probably best known.

The Oryzeae have been produced as a side line from the Phalarideae by a lateral flattening of the spikelet, which contains

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[3] A tribe that has arisen as a side line is one that has been produced by modifications of minor importance. It is, therefore, very closely related to the parent tribe and may very properly be regarded as a sub-tribe.

but one flower. Like the Paniceae the spikelets have the joint below the empty glume. The best known example of the Oryzeae is our common rice.

The Phalaridean Line has also given rise to two small tribes, the Zoysieae and the Tristegineae—each with about thirty species, which are here omitted since they are scarcely known in the United States. They are closely related to the Paniceae, and may be included in that tribe with little difficulty.

THE ANDROPOGONEAN LINE

The Andropogonean Line like the Phalaridean Line is distinguished by having spikelets with larger flowers at the top. In this last line of development are found two tribes, the Andropogoneae and the Maydeae, both distinguished by having many spikelets in pairs (rarely in threes in Andropogoneae) one sessile and the other stalked.

The Andropogoneae which are very similar in appearance to the Paniceae, but of solid stems and generally larger size, include the beard grasses, blue stems, and sorghums. They are characterized by having flowers arranged in pairs or threes, with the central one perfect but the lateral ones pedicellate or stalked, rudimentary, or wanting.

The Maydeae have been evolved from the Andropogoneae by the separation of the spikelets into staminate and pistillate clusters. In *Zea* (our common corn) the ear is the cluster of pistillate flowers; each grain of corn is a pistil and the silk (the style and stigma) runs down from the tip of the ear to each kernel of corn. The tassel at the top of the corn stalk is the cluster of staminate spikelets, in which of course only stamens are produced. In both the ear and the tassel the flowers are arranged in pairs, one stalked and one sessile, showing its derivation from the Andropogoneae.

BOOKS AND CURRENT LITERATURE

Vegetation of the Transcaspian Lowlands.—The desert region to the east of the Caspian Sea, though never thoroughly worked botanically, was explored by Ove Paulsen in 1898–99, on the Second Danish Pamir Expedition, and he has already published various papers on the systematic botany of the region explored. The present volume[1] is largely devoted to the physiognomy of the vegetation of the Transcaspian Desert; it is well illustrated, and what with its clear descriptions, the discussion of formations and growth forms, the accounts of vegetation from selected localities, together with plant lists and statistics, it is possible for one accustomed to such studies to form a satisfactory and relatively complete picture of the distribution and characteristic features of the plant life of the area thus far under investigation.

Omitting further reference to the numerous, often important, details given under the preceding divisions of the work, a brief résumé of the closing chapter, with its main conclusions, is all that will now be attempted. Turkestan and Central Asia were covered by the sea during the Cretaceous and Tertiary periods, and with the emergence of Transcaspia at the beginning of the Quaternary the climate, previously moist and favorable to plant growth, became dry. As a necessary result, the plants of what is now the Transcaspian Desert must die or adapt themselves to new conditions, and at the same time this region became open to immigration from neighboring countries. Under these circumstances a relatively large number of endemic species developed, but the close floristic relationship between Transcaspia and the surrounding country shows that the former has also received a large precentage of its flora by immigration. Of the 768 Transcaspian species enumerated, the endemic species constitute 22 per cent, the remainder being distributed towards the east, north, and south in such percentages as to indicate that a larger number of immigrants are from the south than from any other direction. Most of the genera containing endemic species have their main distribution in the Mediterranean countries and in Western Asia, an indication that the flora of Transcaspia is closely related to the flora of those countries.

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[1] Paulsen, Ove, Studies on the Vegetation of the Transcaspian Lowlands. The Second Danish Pamir Expedition, pp. 279 and map. Copenhagen, 1912.

Of the systematic investigations of individual genera that have been begun the author's report is very brief, but enough is presented to indicate substantial progress, in the course of which the story of ancestral forms and the derivation and migrations of species that have arisen from them since early Tertiary times is, at least in part, being unravelled.

V. M. S.

Soil Fungi.—This paper[1] is the result of a recent investigation on the fungi in arable soils. It consists, in the main, of a monograph of the forms, some of which are new to science, which the author obtained by a method of isolation somewhat different from any that has hitherto been employed in work with soil fungi. This method is carefully described in the paper. Nearly all the forms were found to be obligate saprophytes. As is pointed out, however, failure to isolate certain forms may be due to a lack of suitable media and other environmental factors. Emphasis is laid on the fact that in plant pathological work the application of rational methods of control necessitates, first of all, not merely circumstantial evidence relative to the organism involved but a complete knowledge of its life cycle. It is, of course, generally recognized that even though certain forms are known to hibernate in decaying plant tissues, yet one might not be able to isolate them because they do not grow in culture or only so slowly as to be overrun and their growth thus inhibited. Those who have done any considerable amount of culture work realize that certain facultative parasites seem to have a dormant period during which time growth on media cannot be induced, and that others can be cultured only on sterilized portions of the host or in an extract from it.—Frederick A. Wolf.

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[1] Jensen, C. N., Fungous Flora of the Soil. Cornell Agr. Exp. Sta. Bull. 315: 415–501, figs. 100–134. 1912.

NOTES AND COMMENT

With the settlement of the North American continent and the exploitation of its resources, such as the drainage of its swamps, the removal of the original forests, and the construction of irrigation works in arid districts, the original condition of the land surface and its vegetation will be changed forever. Civilization in the form of agriculture has played sad havoc with native vegetation, destroying, driving back and exterminating most plants, domesticating few. Fire and lumbermen have destroyed our forest wealth. The building of railroad embankments across streams has disturbed the natural drainage and the filling of hollows and valleys with city rubbish has contributed to the same end. Clouds of smoke from locomotives and large manufacturing plants have done much to destroy the native vegetation of our country. Smelter fumes are also responsible for much devastation to vegetation at distances as great as forty miles. But why multiply instances which are familiar to everyone who has the best development of our country at heart, for with this devastation in view, it is important for this generation of botanists and scientists to leave in printed form, in photographs, in maps and in other illustrations a record of the original appearance of the country before the march of civilization has entirely destroyed primeval conditions.

In a series of twelve volumes the writer has assembled photographs, prints, book and magazine illustrations, maps, statistical tables, etc., that depict the natural vegetation of North America, the plants growing under wild conditions, the landscape scenery, the geologic formations (incidentally shown), with the native flora as it existed before the beginning of the year 1912. The collection was started about five years ago, and no trouble was spared to get illustrations which show the original North American vegetation. The year 1911 was chosen as the year in which to finish the collection, because it marked the completion of the writer's Phytogeographic Survey of North America. This compendious volume of 790 pages represents the result of twenty years of travel in various parts of North America, and in its writing ten years of literary labor. The printed book, with only 18 plates and 32 figures in the text, with a colored map, is supplemented by the twelve volumes of

Illustrations of North American Vegetation. The printed volume and the single set of twelve volumes with two supplementary volumes on Foreign Vegetation and Historic Trees, represent one work, the outcome of a conception of what ought to constitute a permanent record of the vegetation of North America, as it existed before the original vegetation had disappeared or been altered irreparable by the destructive agents of man.

The method adopted in mounting the illustrations is described herewith. The illustrations brought together in the fourteen volumes have been mounted on high grade manila paper ($9\frac{1}{2}$ x $11\frac{3}{4}$ in.) in order to conform with the size of the plates in Karsten and Schenck's Die Vegetationsbilder. Bound in light olive green buckram the volumes, it is hoped, will not be subject to rapid deterioration. Thus in a modest way, without undue expense, has been accomplished for North American vegetation what Mr. Edward S. Curtis has done in the publication of his magnificent and sumptuous folios of Indian life in twenty volumes, issued at a cost of $500,000 under the patronage of Mr. J. Pierpont Morgan. Considering the smaller size of many of the photographs in the vegetation collection, it is estimated that there are many times more than the total number in the Curtis collection of Indian pictures.

Some of the photographs included in the volumes of Illustrations of North American Vegetation were taken by the author himself, others were obtained by purchase and exchange, but the major part of the illustrations were obtained from illustrated pamphlets issued by railroad, steamship, hotel and land improvement companies, that have spared no trouble and have gone to great expense to represent pictorially and descriptively the scenic features upon which part of their business depends. Illustrated post cards of real phytogeographic value have been incorporated. Several of the monthly and weekly magazines, such as Recreation, Travel, Outing, Country Life in America, Sunset, National Geographic Magazine, Pacific Monthly, etc., have furnished many valuable pictures, as also the Philadelphia Commercial Museum, which has an extensive series of photographs of the Spanish American countries and other commercial countries of the world. Government publications have yielded a rich harvest of illustrations, originally made at great expense by the various scientific bureaus at Washington. The following have been most prolific sources of illustrative material: the bulletins and reports of the Geological Survey, the Bureau of Plant Industry, the National Herbarium, the Forest Service, and the Biological Survey. Through the courtesy of the secretary of the Pennsylvania

Forestry Association and the Pennsylvania Department of Forestry, a fine collection of views illustrating Pennsylvania vegetation was secured. Illustrations from the Annual Reports of the Missouri Botanical Garden, from duplicate scientific memoirs, obtained from various botanists, have been incorporated. Much assistance has been given by Henry Troth, Charles Gilchrist, O. F. Cook, Roland Harper, G. N. Collins, J. N. Rose, T. L. Garrison, H. L. Shantz, D. T. MacDougal, Silas Schumo, Genji Sato Nakahara, and many others.

The photographs and other illustrations thus obtained have been arranged in the volumes in the sequence of the phytogeographic regions, districts, and areas as set forth in the writer's Phytogeographic Survey of North America, so that each volume of illustrations has headings appropriate to its contents. It is hoped that these volumes will aid the future student of North American vegetation in his literary and research work, and will remain as a permanent record of the vegetation of the country when the present generation of botanists will have ceased from their earthly tasks.[1]—JOHN W. HARSHBERGER.

Professor Bruce Fink and Mr. Vernon Lantis, of Miami University, have published a short paper in The Ohio Naturalist, describing some of the principal environic conditions for vegetation in south-western Ohio in the growing seasons of 1908 and 1909. The former year was marked by a pronounced drought, and the latter by much more than the normal rainfall. Comparative climatological data for these years are given, covering rainfall, temperature, evaporation, and soil moisture. The vegetational conditions for the two seasons are contrasted through descriptions of the weed floras of the two years, of the comparative abundance of fungi and other common cryptogamic plants, of the condition of shade trees on soils of different depth, and through statistics of the yields of leading crops.

In spite of the fact that this piece of work might have been carried out with much greater completeness, the authors deserve commendation for having conceived an investigation of this kind, and having given it so many suggestive ramifications. It seems to be axiomatic in botany, just as in all other fields of human endeavor, that the ground which has been broken will soon attract many hands to its cultivation. It is very much to be hoped, therefore, that Professor Fink will soon have many imitators, studying those aspects of the correlation between climate and

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[1] Read before the American Philosophical Society, April 19, 1912.

vegetation which come near to hand for them. Professor Fink regrets not having had certain pieces of apparatus, notably for the securing of soil samples for moisture determination, but he has secured just as good results by the use of a shovel and tin can, and his example in foregoing an easier but more expensive method is meritorious. The only advice that might be offered on the issue of Professor Fink's work is that anyone who undertakes similar operations should lay out beforehand a very definite plan of action, and first and last he should place only a modicum of reliance on the generalized climatological maps of the Weather Bureau.

It would require some temerity to plan an addition to the already considerable list of books which treat of the history of the biological sciences. When a man has read so widely among the works of the founders, however, that he is impelled to write about them out of sheer pleasure to himself, that even his literary style has been influenced by that of the old natural histories, the result is sure to be pleasing. These appear to be the circumstances under which Mr. L. C. Miall, of Leftwich, England, has written his The Early Naturalists; Their Lives and Work (Macmillan and Company). In some places the author is too biographical and too brief, but through most of the volume he runs on very interestingly, whether talking of the early Greeks or of the middle Eighteenth Century, with which he closes his narrative. Miall has touched even the best known of the founders with a certain freshness, due to his writing more intimately of their personalities and daily lives than most historians have done, and to his relating more about their religious and political environage than most of us have known. Among the less known men, considerable interest attaches to those who made the first records of the natural history of the distant parts of the earth. In spite of its containing much that is being retold, the volume is an eminently enjoyable one.

A correspondent who prefers to remain unnamed sends the following information about that which I described in the June issue of The Plant World as the Kellerman plant press. This is in reality the Riker press, for it was invented by Riker, whose glass and cotton mounts for flowers and insects are well known. My correspondent advises that the press be filled in this order: (1) corrugated board, (2) blotter, (3) specimen, (4) thin paper the specimen lies upon, (5) a sheet of cotton batting with a thin sheet of paper on each side of it, (6) thin paper on which lies (7) a specimen, (8) blotter, (9) corrugated board, and so on. This sounds elaborate, but my correspondent puts up about 4000 specimens in a summer, as hobby work, and has used his methods in travels to distant places. My own results without such special care are satisfactory for purposes of teaching. My correspondent further writes: "I use instead of a lamp a No. 2 lantern, which is much safer, and I lay my press on a frame about 24 ins. high. I also always bring the ducking that surrounds the press fully up to the top and tie it around the top. This forces the draught of air through the whole press."

I am glad to submit these corrections and additions, hoping only to spread the knowledge of this quick, easy and efficient method of drying plants.—Henry S. Conard.

Professor Samuel J. Record, of the Yale Forest School, has written a text and reference book entitled Economic Woods of the United States (John Wiley and Sons). The principal anatomical features of wood are discussed, both in their relation to its physical properties and with respect to their value as diagnostic characters for the identification of the wood of different tree species. An extended key for the determination of woods is a feature of the book, together with a few tables of physical properties of timber, about forty microphotographic illustrations of wood sections, and full citations of literature under each anatomical topic and each species of tree.

Copies of the Montgomery Advertiser and the Tuscaloosa News which have been sent us by a correspondent indicate that considerable interest is being manifested in Alabama in the visit which Professor De Vries is making to the type locality of *Oenothera lamarckiana*, at Dixie Landing, near Mobile. Men of science are rare in the south-eastern states, and appreciated by the general public perhaps less than in any other section of the United States. It is particularly gratifying, therefore, to find that the local scientists of Alabama have seen to it that their daily papers contain accurate and appealing accounts of Professor De Vries and his work.

THE HEAT PRODUCED BY LEAVES

MILDRED SPARGO

Missouri Botanical Garden, St. Louis, Mo.

In the spring of 1911 my attention was called to an article in the Botanische Zeitung for December, 1908, by Hans Molisch, "Ueber hochgradige Selbsterwärmung lebender Laubblätter," in which he gave an account of his experiments on the heat produced by leaves. He took every precaution to prevent loss of heat by radiation and transpiration, packing the flasks containing the leaves in sawdust, and keeping them in a cool room. He obtained some remarkable rises in temperature, which he attributed mainly to respiration, partly to chemical changes, and, in those cases where the temperature rose far above the thermo-death point, to "tote-oxidation." He also mentions ferments and enzymes as possible sources. In all cases he continued reading the temperatures until he obtained a second rise, which he interpreted as being due to the growth and work of microörganisms.

His experiments are interesting, and his statements well borne out by the results obtained from them. His theory, that the production of heat by leaves, whether attached, or detached from the mother plant, is due almost solely to respiration has been generally accepted, and certain interpretations of respiration by some investigators are based largely on his results and the conclusions therefrom. A general summation of his experiments is best stated in his own words;—"lebende frische Laubblätter vieler Pflanzen, vom Sprosse abgetrennt und in grosseren Massen beisammenliegend, sich binnen wenigen Stunden, ohne Intervention von Microorganismen, hochgradige erwarmen, oft so stark, dass sie infolge der selbst erzeugten Wärme vom Tode ereilt werden."

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Carefully observing all of his precautions, an attempt was made to duplicate his experiments. He used a flask covered with wicker packed in a wooden box filled with sawdust, and performed his experiments in a north room where the temperature was low and fairly constant.

The experiments herein reported were carried on in a basement room, where the temperature was rarely higher than 22°C., and varied not more than 5° or 6°. In the earliest experiments, Dewar flasks were used. These were placed in wooden boxes and tightly packed with excelsior. The only part of the flask uncovered was the upper rim of the neck, which was covered with paraffin to obviate any leakage should the cork not fit perfectly. The bulb of the thermometer, in every case, was in the mass of leaves.

Freshly picked, dry leaves were used (dampness would prevent free interchange of air, and would hasten decomposition), and their weight determined. Molisch used from 3.5 to 5 kg. of leaves, never less. Though he gave no dimensions of his apparatus, from the figure accompanying the article it appears to have been a regulation laboratory carboy in its box.

The half-litre Dewar flasks used held in no case more than 75 grams. As no results were obtained in the experiments, flasks of larger capacity were employed in succeeding experiments. The following flasks were used;—the half-litre Dewar flasks; 2-litre flasks, which held from 170 to 225 grams; 4-litre flasks, holding 300 to 325 grams (the latter were wrapped in thick folds of soft paper and closely packed in excelsior in a wooden box); and a large carboy of about 12 gallons capacity. This was of thick glass, and was firmly packed in excelsior in a strong wooden box. Not more than 3 kg. of the smallest leaves could be packed into this large carboy, and the question arises as to what means Molisch used to get 5 kg. into a flask apparently no larger.

As the tables given below indicate, the leaf-masses used did not affect the results in any way. Attempts were then made to see if the quantity of leaves in a given flask affected the result. One Dewar flask was tightly packed with young *Sedum* leaves, the weight used being 70 grams. Another was lightly filled with just half the amount. As will be noted (table 1) this had no effect on the temperatures.

According to Molisch, the rises in temperature can not be attributed to the respiration and work of microörganisms, since he was, in several cases, careful to examine the leaves immediately after the first maximum, and, though finding the leaves brown and dead, they were apparently free from microörganisms. However, after four days (the time of the second maximum) he found the leaves overgrown with microörganisms, chiefly fungi. In only one case in our experiments were any fungal growths evident, (and these but slight) and in very few was there any evidence of bacterial growth.

As will be seen from the tables, it was impossible in any way to duplicate the results obtained by Molisch. In only two experiments was there any appreciable rise in temperature. The first, in leaves of *Tilia,* (table 5) which rose 6.4° in seven hours, is easily explained when the first reading of the Dewar flask is noted. The leaves were picked in the sunshine on a hot day, and immediately placed in the flasks. The temperatures, as is observed, differ by only one degree (due to the much greater mass in the carboy) which proves that the heat exhibited by the leaves in the carboy was simply a result of the previous external temperature.

The leaves exhibiting the other rise in temperature were *Robinia.* As will be noticed (table 6, B), the rise did not come for six days (after which length of time Molisch found plentiful growth of microörganisms) and, as stated in the table, the condition of the leaves gave strong evidence of bacterial decay.

Molisch used leaves which were fully mature, their period of growth past, while the leaves first used in our experiments were very young, growing in the open in the early spring. Since in young leaves respiration is often more intense than in fully grown leaves, one would suppose that more positive results would be obtained in the spring than in the fall. However, in order that all the conditions under which Molisch worked would be as nearly duplicated as possible, experiments were made in the months of September and October, when the leaves were in the same condition as those used by Molisch. Again negative results were obtained.

The accompanying tables give the results of experiments carried on in precisely the same manner, and under exactly the conditions described by Molisch. It will be noticed that leaves of various forms and degrees of succulency were used;—the membranaceous ones of *Pirus*, subcoriaceous leaves of *Vitis*, coriaceous leaves of *Hydrangea*, the tomentose ones of *Tilia*, succulent, closely growing leaves of *Sedum*, and the compound leaves of *Robinia* and *Daucus*.

As will be noted, the readings were sometimes continued for 14 days or more, to obtain a possible rise from fungal or bacterial growths—Molisch's "second maximum."

TABLE 1

Sedum acre

These experiments were carried on in two sets, in one (*A*) of which the injury to the leaves was reduced to a minimum, as the whole cluster was used. In the second set (*B*) the leaves were cut. Only Dewar flasks were used, 70 grams of leaves being used in each case with one exception, which has been explained. The plants were quite young, growing in the open, in March. The experiments extended from March 9 to March 14.

Set A

DAY	HOUR	TEMPERATURES OF		
		Room	Dewar A	Dewar B*
		degrees	*degrees*	*degrees*
March 9, 1911	2.00 p.m.	21.0	20.0	21.6
	3.30 p.m.	18.0	20.2	21.0
	5.00 p.m.	19.0	20.5	21.0
	6.00 p.m.	18.7	20.5	20.8
	7.30 p.m.	17.8	21.0	20.5
	8.30 p.m.	17.0	21.0	20.0
	10.00 p.m.	16.0	21.0	20.0
	11.00 p.m.	16.5	21.0	20.0
March 10	8.00 a.m.	16.0	19.5	17.0
	10.00 a.m.	16.0	19.0	18.0
	12.00 p.m.	16.2	18.8	18.0
	1.00 p.m.	16.4	18.6	17.8
	3.30 p.m.	16.5	18.0	18.0
	6.00 p.m.	16.6	18.0	17.0
	10.00 p.m.	16.6	17.8	17.0
March 11	8.00 a.m.	15.8	17.0	17.6
	9.00 a.m.	16.0	17.0	17.6
	3.00 p.m.	16.0	16.8	17.5

Set B

March 11	6.00 p.m.	19.0	22.5	23.5
	7.00 p.m.	18.0	21.5	22.5
	9.00 p.m.	18.0	20.5	21.5
March 12	8.00 a.m.	17.0	19.0	20.0
	10.00 a.m.	17.0	19.0	19.7
	12.00 p.m.	17.0	18.5	19.3
	1.00 p.m.	17.0	18.5	19.0
	2.00 p.m.	17.0	18.2	18.7
	3.00 p.m.	16.5	18.0	18.7
	5.00 p.m.	16.5	17.8	18.3
	6.00 p.m.	16.5	17.5	18.2
March 13	7.30 a.m.	16.0	16.2	16.8
	12.00 p.m.	16.5	16.0	16.5
	3.00 p.m.	16.5	16.0	16.2
	5.00 p.m.	16.2	16.0	16.0
	10.00 p.m.	16.2	16.0	16.2
March 14	7.00 a.m.	16.0	15.8	16.0
	9.00 a.m.	16.0	15.8	16.0

* Containing 35 grams.

When the leaves were removed on March 11 (third day), decomposition had begun in flask A, but the leaves were fresh and green in flask B, where aeration was better. In Set B, there was a small amount of bacterial decomposition in both flasks.

TABLE 2

Vitis indivisa

These leaves were large and fully grown, from plants in the greenhouse. No readings were taken from the third to the fifth day, as the temperatures remained constant until the leaves were removed. In both cases the leaves were fresh and green when removed. The experiments were begun on March 14, ended March 18.

DAY	HOUR	TEMPERATURES OF		
		Room	4-litre flask*	2-litre flask†
		degrees	*degrees*	*degrees*
March 14	6.00 p.m.	16.2	15.2	16.0
	7.45 p.m.	16.4	17.7	15.8
	9.30 p.m.	16.0	17.2	15.8
	11.00 p.m.	16.0	16.8	15.6
March 15	8.20 a.m.	14.4	15.2	14.4
	9.30 a.m.	14.4	15.0	14.2
	3.15 p.m.	13.8	14.2	13.0
	5.30 p.m.	14.0	14.0	13.0
	7.00 p.m.	14.0	14.0	13.0
	10.00 p.m.	14.0	14.0	13.0
March 16	9.00 a.m.	14.0	14.0	14.0
	3.00 p.m.	14.0	14.0	14.0

* Containing 325 grams.

† Containing 170 grams.

In his experiment with *Vitis vinifera,* Molisch found the "first maximum" rise, of 43.3°, within twenty-eight hours at a room temperature of about 17°. The "second maximum" was 44.3°; the length of time was not stated

TABLE 3

Hydrangea sp.

Experiment begun March 18, 1911, ended March 21, 1911. Leaves taken from greenhouse plants, fully grown.

DAY	HOUR	TEMPERATURES OF			
		Room	Dewar flask*	2-litre-flask†	Carboy‡
		degrees	*degrees*	*degrees*	*degrees*
March 18......	12.30 p.m.	15.2	17.2	17.2	
	2.00 p.m.	15.3	17.8	17.0	
	3.00 p.m.	16.0	17.8	16.8	
	4.00 p.m.	17.8	17.9	17.0	
	5.00 p.m.	17.5	18.0	16.5	
	7.00 p.m.	16.5	18.0	16.5	
	9.00 p.m.	16.5	17.8	16.2	16.2
March 19......	10.00 p.m.	16.0	18.0	16.0	16.2
March 19......	9.00 a.m.	15.8	17.0	16.0	16.0
	10.00 a.m.	15.8	17.0	16.0	16.0
	11.00 a.m.	16.0	17.0	15.2	16.0
	12.00 a.m.	16.1	17.0	15.2	16.0

* Containing 60 grams.

† Containing 235 grams.

‡ Containing 3 kg.

Temperatures were observed until March 22, but were not recorded as they continued the same. The leaves were fresh and green when removed.

TABLE 4

Daucus carota

In this case injury was reduced to a minimum, as the petiole was cut at some distance from the first leaflet. The experiment was begun March 21, 1911 and ended March 25, 1911. Most of these were fully grown leaves, from the greenhouse.

DAY	HOUR	TEMPERATURES OF			
		Room	Dewar flask*	4-litre flask†	Carboy‡
		degrees	*degrees*	*degrees*	*degrees*
March 21	1.00 p.m.	18.8	20.3		
	2.00 p.m.	18.2	20.6		14.3
	3.00 p.m.	18.0	20.6	18.0	15.0
	4.00 p.m.	17.9	21.2	18.0	14.5
	6.00 p.m.	18.0	21.0	17.0	15.0
	8.00 p.m.	19.0	21.3	17.0	17.5
	10.00 p.m.	17.5	21.4	17.3	17.8
March 22	8.00 a.m.	17.5	19.5	17.3	17.5
	11.00 a.m.	17.3	19.0	17.2	17.5
	1.00 p.m.	17.4	18.5	17.2	17.5
	3.00 p.m.	17.3	18.4	17.1	17.4
	5.00 p.m.	17.3	18.2	17.0	17.3
	7.00 p.m.	17.2	17.9	17.0	17.1
	9.00 p.m.	17.2	17.8	16.9	17.3
	10.00 p.m.	17.4	17.8	17.0	17.3
March 23	8.00 a.m.	17.4	17.5	16.9	17.0
	9.00 a.m.	17.5	18.0	17.2	16.8
	3.00 p.m.	17.0	17.2	17.2	16.8

* Containing 50 grams.

† Containing 300 grams.

‡ Containing 2 kg.

When removed, on March 25, decomposition had begun in the Dewar flask, but the leaves in the two larger flasks were fresh and green.

TABLE 5

Tilia Americána

Leaves young, picked May 6 1911. Experiment ended May 10, 1911. Where there is a considerable lapse between readings, the temperatures remained constant.

DAY	HOUR	TEMPERATURES OF			
		Room	Carboy	2-litre flask	Dewar flask
		degrees	*degrees*	*degrees*	*degrees*
May 6.........	3.00 p.m.	17.0	19.8	19.0	25.2
	4.00 p.m.	17.0	21.2	19.5	25.5
	6.00 p.m.	17.0	23.0	19.2	25.0
	7.00 p.m.	16.5	25.0	19.0	25.0
	8.30 p.m.	16.5	25.2	18.5	25.0
	10.00 p.m.	16.5	26.2	18.0	24.8
May 7.........	8.00 a.m.	16.0	23.0	15.5	
	9.00 a.m.	16.0	23.0	15.5	24.0
	11.00 a.m.	16.0	22.8	15.5	24.0
	12.00 p.m.	16.5	22.5	15.5	22.5
	1.00 p.m.	16.6	21.2	15.5	21.5
May 8.........	7.00 a.m.	16.5	23.0	15.5	17.0
	9.00 a.m.	16.5	22.0	15.5	17.0
	9.00 p.m.	17.0	21.0	16.5	17.0
May 9.........	8.00 a.m.	18.0	19.3	15.5	17.6
	11.00 a.m.	19.0	20.0	17.5	17.6
	1.00 p.m.	18.2	20.2	17.5	18.0

When the leaves were removed, on May 9, various changes were noticed. In the carboy, many leaves were brown and damp, others fresh and green. Also there was considerable odor of decay. In the 2-liter flask, there was no evidence of decay, though the leaves were somewhat brownish. In the Dewar flask, the leaves were quite brown, and withered. There was a very noticeable odor, and considerable soft bacterial decay.

For *Tilia* sp., Molisch records a maximum of 50.8°, the room temperature being on the average 18°, in 27.5 hours. The "second maximum" was 52.1°; length of time not given.

TABLE 6-A (SPRING)

Pirus communis

Leaves quite young, picked out of doors May 5. Experiment ended May 4, 1911.

DAY	HOUR	TEMPERATURES OF			
		Room	Carboy*	2-litre flask†	Dewar flask‡
		degrees	*degrees*	*degrees*	*degrees*
May 1	5.00 p.m.	15.0	19.0	18.0	18.0
	6.00 p.m.	15.0	20.5	19.0	19.0
	8.00 p.m.	15.0	21.0	17.0	19.5
	9.00 p.m.	15.0	21.5	16.0	20.0
	11.00 p.m.	15.0	22.5	16.0	20.5
May 2	7.00 a.m.	15.0	18.5	15.0	17.2
	8.00 a.m.	15.0	18.5	15.0	17.2
	9.00 a.m.	15.0	18.5	15.0	17.0
	10.00 a.m.	15.0	18.0	14.8	16.5
	11.00 a.m.	15.0	18.0	14.8	16.5
	12.00 p.m.	15.0	18.0	14.8	16.5
	1.00 p.m.	15.0	17.8	14.8	16.2
	2.00 p.m.	15.0	17.5	14.8	16.0
	3.00 p.m.	15.0	17.5	14.8	16.0
	4.00 p.m.	15.0	17.5	14.8	16.0
	7.00 p.m.	15.0	17.5	15.0	16.0
	10.00 p.m.	15.0	17.5	15.0	16.0
May 3	8.00 a.m.	15.5	17.5	15.2	15.8
	10.00 a.m.	15.5	17.5	15.5	15.8
	11.00 a.m.	15.8	17.5	15.8	16.0
	1.00 p.m.	16.0	17.5	15.8	16.0
	4.00 p.m.	15.5	17.5	15.8	16.0
	10.00 p.m.	15.5	17.5	16.0	16.2
May 4	8.00 a.m.	16.0	17.5	16.0	16.2
	1.00 a.m.	16.0	16.0	16.0	16.0
	3.00 p.m.	16.0	16.0	16.0	16.0

* Containing 3 kg.

† Containing 385 grams.

‡ Containing 35 grams.

When the leaves were removed, on May 4, those in the carboy had begun to decompose; those in the 2-litre and Dewar flasks were brownish, many of them decidedly brown, and spotted, and had a noticeable odor of fermentation.

TABLE 6–B (AUTUMN)

Pirus communis

These were fully grown leaves, picked Oct. 4 1911. Readings were taken for five days.

DAY	HOUR	TEMPERATURES OF			
		Room	Dewar A	Dewar B	Carboy
		degrees	*degrees*	*degrees*	*degrees*
October 4	4.00 p.m.	22.0	27.9	27.2	
	6.00 p.m.	22.0	29.3	28.0	
October 5	9.00 a.m.	20.4	24.1	23.0	
October 6	9.00 a.m.	21.7	21.7	21.3	
	12.00 p.m.	22.0	21.8	21.5	
	3.00 p.m.	25.5	22.1	21.8	
	5.00 p.m.	23.8	22.5	22.1	
	8.00 p.m.	22.5	23.0	22.8	26.0
October 7	9.00 a.m.	19.5	20.9	20.6	20.7
	12.00 p.m.	18.0	20.5	20.0	21.0
	4.00 p.m.	17.5	20.0	19.7	20.0
October 9	7.00 a.m.	19.5	19.5	19.2	19.2
	9.00 a.m.	19.0	19.5	19.3	19.2
	12.00 p.m.	19.0	19.5	19.3	19.2
	3.00 p.m.	18.9	19.8	19.3	19.0

The leaves were not taken out of the Dewar flask until October 20. Then they were brownish and dead, had a slight odor of fermentation, but showed no evidences of bacterial work, and no fungi. The leaves in the carboy were slightly damp, brownish, some decidedly brown, and had a decided odor of fermentation. There was no bacterial or fungal growth.

For *Pirus communis* Molisch reports a rise to 59° in sixteen hours, the room-temperature hanging from 14° to 18°. The "second maximum" was 48.2°, after five days. At the end of fourteen days the leaves were removed, and found to be brown, dead, and overgrown with microorganisms, chiefly fungi.

TABLE 7-A (SPRING)

Robinia pseud-acacia

These leaves were young, and picked in the sun on a bright day. The experiments were begun on May 9, and readings taken until May 25 to obtain a possible rise from fungus or bacterial growths.

The leaves were brown, dry, and quite odorous when removed from the flasks, but there were no visible fungus growths.

DAY	HOUR	TEMPERATURES OF		
		Room	2-litre flask	Dewar flask
		degrees	*degrees*	*degrees*
May 9	5.00 p.m.	19.0	23.8	25.0
	7.00 p.m.	19.0	23.0	27.0
	8.00 p.m.	19.0	21.0	26.0
	9.00 p.m.	19.0	20.0	25.0
	10.00 p.m.	19.0	20.0	24.2
	11.00 p.m.	19.0	19.8	23.2
May 10	6.00 a.m.	18.5	18.2	20.2
	7.00 a.m.	18.5	18.0	20.0
	9.00 a.m.	19.5	18.0	20.0
	12.00 p.m.	19.0	18.0	19.8
	2.00 p.m.	19.2	18.2	19.8
	4.00 p.m.	19.5	18.5	19.2
	7.00 p.m.	19.5	18.8	19.0
	11.00 p.m.	19.5	19.0	19.0
May 11	6.00 a.m.	19.5	19.0	19.2
	9.00 a.m.	19.0	19.0	19.0
	12.00 p.m.	19.8	18.4	19.0
	2.00 p.m.	20.5	18.3	19.0
	6.00 p.m.	19.5	18.5	19.0
	10.00 p.m.	19.0	18.5	19.0
May 12	7.00 a.m.	18.0	17.5	18.2
	10.00 a.m.	18.8	17.8	18.2
	12.00 p.m.	19.0	17.8	18.2
	4.00 p.m.	19.2	18.0	18.2
	No change	until		
May 13	9.00 a.m.	19.0	18.0	18.0
	1.00 p.m.	20.0	18.0	18.0
	11.00 p.m.	19.5	18.5	18.8
May 14	7.00 a.m.	19.0	18.5	19.0
	3.00 p.m.	20.0	19.0	19.0
	No change	until		
May 16	8.00 a.m.	20.2	19.2	19.8
	5.00 p.m.	21.0	20.0	20.0
May 17	7.00 a.m.	21.0	20.0	20.5
	6.00 p.m.	21.2	20.8	12.8
May 18	6.00 a.m.	21.5	20.8	21.0
	9.00 a.m.	22.2	21.0	21.0
	12.00 p.m.	22.4	21.0	21.0

Temperatures constant until leaves were removed, May 25, 1911.

TABLE 7-B

Robinia pseud-acacia

These leaves were fully grown, picked September 28, 1911, in the morning of a warm, humid, rather cloudy day.

DAY	HOUR	TEMPERATURES OF			
		Room	Dewar A*	Dewar B†	Carboy‡
		degrees	*degrees*	*degrees*	*degrees*
September 28..	11.00 a.m.	23.2			
	12.00 p.m.	20.0	28.1	29.0	28.0
	2.00 p.m.	26.0	30.3	31.6	29.2
	3.00 p.m.	24.5	31.0	30.5	30.5
	5.00 p.m.	25.5	30.4	29.5	30.2
	8.00 p.m.	24.5	28.8	28.3	30.0
September 29..	9.00 p.m.	23.5	24.3	24.6	28.0
	11.00 a.m.	23.5	24.1	24.4	28.8
	1.00 p.m.	23.4	24.0	24.0	28.8
	3.00 p.m.	23.2	23.8	23.8	28.8
	5.00 p.m.	23.1	23.8	23.5	28.0
September 30..	9.00 a.m.	21.5	22.0	22.0	22.5
	2 00 p.m.	22.3	22.0	22.0	24.0
September 1.....	2.00 p.m.	22.6	22.7	23.5	26.0
September 2.....	9.00 a.m.	20.0	22.5	24.2	25.0
Septemer 3....	9.00 a.m.	21.5	22.7	23.6	28.0
	11.00 a.m.	22.5			28.0
	3.00 p.m.	22.2			28.0
	4.00 p.m.	22.0			28.0
	6.00 p.m.	22.0			27.0

* Containing 33 grams.

† Containing 38 grams.

‡‡ Containing 2 kg.

When removed, on October 4, the leaves in the Dewar flasks were brownish, and the odor indicated that some fermentation had taken place. The leaves in the carboy were rotted, and there was a slight growth of fungus.

Molisch's results are given in the comparative table.

COMPARATIVE TABLE

Pirus communis

DAY		HOUR		TEMPERATURE ROOM		TEMPERATURE LEAVES	
Molisch	Spargo	Molisch	Spargo	Molisch	Spargo	Molisch	Spargo
				degrees	*degrees*	*degrees*	*degrees*
September 23, 1907	October 6, 1911	12.30 p.m.	5 00 p.m.	15 0	23.8	14.4	26.8
		5.00 p.m.	8.20 p.m.	15.0	22.5	18 1	26.0
September 24	October 7	10 00 p.m.	9 00 a.m.	15.0	19.5	24.0	20.7
		5.00 a.m.	12.00 a.m.	14.5	18 0	35.2	21.0
		8.00 a.m.	4.30 p.m.	14.5	17.5	41.6	20.0
	October 8	10.00 a.m.	9.00 a.m.	14.5	19.0	46.2	19.2
		11.30 a.m.	10.00 p.m.	14.5	19.0	49.1	19.2
		12.30 p.m.	12 30 p.m.	14.5	19.0	52.0	19.2
		2.30 p.m.	3 00 p.m.	14.5	18.9	54.0	19.0
		4.00 p.m.		14.9		*59.0*	
		4.45 p.m.		14.9		56.4	
		6.15 p.m.		14.9		53.5	
		7.30 p.m.		14.9		54.9	
		9.45 p.m.		14.9		53.0	
September 25		4.00 a.m.		14.5		46.2	
		5.30 a.m.		14.5		44.6	
		10.00 a.m.		14.5		42.0	
		12.00 p.m.		14.5		39.8	
		2.15 p.m.		14.9		38.4	
		9.00 p.m.		15.0		35.2	
September 26		4.00 a.m.		15.0		33.6	
		7.30 a.m.		15.0		33.2	
		7.00 p.m.		15.2		34.2	
		9.00 p.m.		15.2		34.8	

September 27		5.00 a.m.		15.2		38.0	
		9.30 a.m.		15.2		41.3	
		12.00 p.m.		15.2		43.0	
		2.30 p.m.		15.2		44.2	
		8.00 p.m.		15.2		45.8	
		10.00 p.m.		15.2		46.8	
September 28		7.00 a.m.		15.2		48.0	
		4.30 p.m.		15.5		48.2	
		9.00 p.m.		15.5		48.0	
September 29		6.00 a.m.		16.0		47.7	
		5.00 p.m.		16.3		47.0	
		9.00 p.m.		16.5		46.7	
September 30		5.00 a.m.		17.0		45.9	
		12.00 p.m.		17.2		45.4	
		7.00 p.m.		17.2		44.5	
October 1		6.00 a.m.		17.8		43.0	
		Gradually	decreasing	until			
October 7		12.00 p.m.		16.5		22.0	

COMPARATIVE TABLE

Robinia pseudacacia

DAY		HOUR		TEMPERATURE ROOM			TEMPERATURE LEAVES		
Molisch	Spargo	Molisch	Spargo	Molisch	Spargo		Molisch	Spargo	
				degrees	*degrees*		*degrees*	*degrees*	
July 2, 1907....	September 28, 1911...	6.00 p.m.	12.00 p.m.	24.5	23.0	19.0	23.0	28.0	23.8
		7.00 p.m.	2.30 p.m.	24.5	26.0	19.0	24.1	29.2	23.0
		9.00 p.m.	3.30 p.m.	24.5	26.0	19.0	28.5	30.5	21.0
July 3..........		5.00 a.m.	5.30 p.m.	24.0	25.5	19.0	48.2	30.2	20.0
	September 29.........	6.00 a.m.	8.00 p.m.	24.0	24.5	19.0	50.1	30.0	20.0
		7.00 a.m.	9.15 a.m.	24.0	23.5		*51.0*	28.0	19.8
		9.00 a.m.	11.00 a.m.	24.0	23.5		49.9	28.8	18.2
		11.00 a.m.	1.00 p.m.	24.0	23.5		49.8	28.8	18.0
		12.00 p.m.	3.00 p.m.	23.0	23.2		49.3	28.8	18.0
		1.00 p.m.	5.00 p.m.	23.0	23.1		48.8	28.0	18.0
	September 30.........	1.50 p.m.	8.00 a.m.	23.0	21.5		48.2	22.5	18.2
		3.45 p.m.	2.00 p.m.	23.0	22.3		47.1	24.0	18.5
	October 1..............	5.00 p.m.	2.00 p.m.	23.0	22.6		46.6	26.0	18.8
	October 3..............	6.00 p.m.	9.00 a.m.	23.0	20.0		46.2	25.0	19.0
	October 4............	10.00 p.m.	9.00 a.m.	22.5	21.5		45.2	28.0	19.0
July 4.........		5.15 a.m.	11.00 a.m.	22.0	22.5		45.4	28.0	19.0
		7.15 a.m.	3.00 p.m.	22.0	22.2		45.9	28.0	18.4
		10.15 a.m.	4.00 p.m.	22.0	22.0		46.5	28.0	18.3
		12.00 p.m.	6.00 p.m.	22.0	22.0		46.0	27.0	18.5
	October 5..............	4.20 p.m.	8.00 a.m.	22.0	20.4		47.6	27.0	18.5
	October 6............	6.00 p.m.	9.00 a.m.	22.0	21.7		47.7	26.0	17.5
		9.45 p.m.		22.0			49.5		
July 5..........		4.30 a.m.		21.5			52.0		
		9.00 a.m.		21.5			52.5		

July 5.		1.00 p.m.		21.5			53.0		
		5.00 p.m.		22.4			53.8		
		10.00 p.m.		22.8			54.3		
July 6.		4.30 a.m.		23.0			54.5		
		7.45 a.m.		23.1			56.5		
		10.00 p.m.		23.2			57.0		
		12.00 p.m.		23.5			57.0		
		2.35 p.m.		23.5			57.0		
		7.00 p.m.		23.5			57.1		
		10.00 p.m.		23.5			*57.2*		
		Temperature then fell until final reading							
		9.30 p.m.		21.0			33.3		

The second column of figures under "Leaf temperatures" are those obtained from the experiments in the spring. In the spring, readings were continued until May 18, but, as the temperature of the leaves continued to keep with those of the room, it was not thought necessary to put them in this table. The final reading was May 19, 1911, 12 p.m., Room, 22.4; Leaves, 21.0°.

NOTES ON THE ANATOMY OF OPUNTIA LINDHEIMERI ENGELM.

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Since the publication of Schleiden's[1] Anatomie der Cacteen, numerous workers have contributed to our knowledge of the histology of cacti. Any one who has studied this group of plants is well aware of the fact that there is yet much to be understood concerning them. It is evident, upon further study, that in a recent paper,[2] I did not record correctly the structure of certain tissues and consequently am in error in regard to their nature. It is, therefore, the purpose of this paper to rectify these errors and to contribute other additional observations.

Among these plants there would seem to be no doubt that the formation of cork, one of the most common phenomena which is known to occur, is of pathological origin.[3] In order to better understand the changes which take place in cork formation in *Opuntia lindheimeri*, it is necessary to indicate the arrangement of tissues in a normal plant. As shown in figure 3, the outer epidermal wall is strongly cuticularized. The hypodermal layer, subjacent to the epidermis, contains large calcium oxalate crystals. Between the hypoderma and the chlorenchyma is a layer of collenchyma 3 to 5 cells thick, the walls of which are stratified and coarsely porous. As Schleiden has shown, cork formation begins

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[1] Schleiden, M. J., Beiträge zur Anatomie der Cacteen. Mémoires de l'Academie Impériale de Sciences de St. Petersburg. Ser. 6, T. **4**: 335–380, pls. 1–10 (1839), 1841.

[2] Wolf, F. A., Some fungous diseases of the prickly pear, *Opuntia lindheimeri* Engelm. Ann. Myc. **10**: 8–134, pls. 1–3 + figs. 8, 1912.

[3] Hillhouse (vide Strasburger and Hillhouse, Practical Botany, p. 188, 1908) suggests that it seems probable that all cork has phylogenetically a pathological origin.

by a tangential division of the epidermal cells (fig. 5). The inner layer of daughter cells then becomes the initial phellogenetic layer. It is, therefore, by the successive division of this initial layer that the cork tissue above becomes progressively thicker.

There often appear, on the segments, rusty brown areas beginning usually in the areolae of the spines. Sorauer[4] is of the opinion that these may be due to unfavorable atmospheric influences. This condition may also be due, in part at least, as I have previously pointed out, to the presence of a fungus, *Hendersonia opuntiae.* These areas may remain superficial so that the epidermis alone is concerned in initiating cork formation. At other times more deeply seated layers may be involved, indicating that any part of the epidermal and fundamental tissue systems may generate cork. One of the diseased areas of the latter type is represented diagrammatically in figure 1. A thick layer of cork formed by the epidermis, hypoderma, collenchyma and palisade parenchyma separates the discolored area from the surrounding tissue. The margin of one of these areas is shown in detail in figure 10. When this pathological condition occurs, the stomata in the affected area are barred by the formation of cork. As far as can be learned no one has properly illustrated or described the manner in which this is brought about. Schleiden's illustrations and my own do not give any idea of the process. As indicated by the dotted line in figure 3, the initiation of this process consists in a division of the accessory guard cells parallel to their inner wall. The lowermost cell becomes the phellogenetic cell for the series of successive divisions which follow. As growth continues, a slight protrusion and enlargement results in the closure of the small space that is always present between normal accessory guard cells. An advanced stage in this process of barring is exemplified in figure 4, from which the manner in which this phenomenon is brought about is readily apparent. Often too, the crystal-bearing hypodermal cells protrude into the substomatal opening, as shown in figure 2, closing it partially or entirely.

Contrary to my previous account, the thick walled tissue, in-

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[4] Sorauer, P., Handbuch der Pflanzenkrankheiten 1: 427–430, 1909.

terposed in layers within thin-walled cork-tissue, is not collenchyma but cork. Neither is it collenchyma tissue which forms the callous layer in case of wounds arising from perforations either by anthracnose or mechanical injuries. To the peculiar kind of cork which is formed in these cases the name *stone cork* is applied. If one attempts to recognize *all* cork tissue microscopically after having formulated his ideas of its nature from the accounts and illustrations in many of our text-books, he will probably be in error. Cork may not only consist of tabular thin-walled cells but the walls may be more or less modified by secondary thickening. This secondary thickening may in some cases, as in the beech, be quite uniform. On the other hand the outer wall may be much more strongly modified as in the willow and pear and as is also the case in *Opuntia lindheimeri*. Neither the willow nor the pear, however, have such strongly thickened tissue as the cactus, neither do their cork cells have pitted walls. In the case of *Viburnum opulus* the inner wall has the greater thickness.

Again, a microchemical test alone will not furnish conclusive proof. Frequently cork tissue will be found which is suberized throughout its entire thickness, as shown on treatment with a solution of alkanet. Mohl[5] has shown that in *Boswellia papyrifera* the cork tissues are silicified. Haberlandt,[5] because of the chemical reactions with proper reagents, concludes that cellulose and ligneous substances may in some cases be present. The presence of cellulose in cork tissue was confirmed by the later researches of Gilson and van Wisselingh.[5] Because of the fact that the stone cork cells of cacti yield so readily the characteristic reactions for cellulose, I was led to believe that they were collenchymatous. When, however, one takes into account the origin of this tissue, he is presented with convincing evidence of its nature. Because of the fact that the stone cork cells are arranged *seriatim* just as are the adjacent thin-walled cork cells, and that several layers may be formed, separated by thin-walled cork tissue (fig. 9), it is very evident that both kinds of cork cells arise

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[5] Vide DeBary's Comparative Anatomy of the Phanerogams and Ferns, 1884, and Haberlandt's Physiologische Pflanzenanatomie, 1909.

from the same initial layer. Figure 8, which is taken from the margin of one of the discolored areas, shows that the stone cork is merely a secondary modification of the thin-walled cork. Not infrequently this tissue is several cell layers in thickness (fig. 6). The cell layers are not always continuous but they may be one cell thick in some places and two or three cells thick in others immediately adjacent (fig. 7).

The stone cork cells of cacti, which were previously misrepresented both by Schleiden and myself, are thickened along the outer and lateral walls, leaving a portion of the inner wall very thin. Since the secondary thickening is not uniformly refractive, the cell walls appear to be stratified. In case the tissue is more than one cell layer in thickness, minute pores or canals extend from the lumen of the lower cell to that of the one above (fig. 6). In single cell layers the walls are not pitted. The thickened wall of the upper cell in a series is never porous. The position of these canals or pits indicates that the active phellogen is always on the inside of the zone of stone cork.

EXPLANATION OF FIGURES

1 Diagrammatic representation of a section through one of the diseased areas, showing the way in which cork tissue separates the brown areas from the active tissues below. *a*, cuticle; *b*, cork; *c*, crystal bearing hypoderma; *d*, collenchyma.

2 Protrusion of crystal bearing hypodermal cells into the substomatal cavity.

3 Normal stoma: *a*, cuticle; *b*, epidermis; *c*, hypoderma; *d*, collenchyma; *e*, accessory guard cells; *f*, true guard cells. The dotted line marks the position of the first division of the epidermal cells in barring the stomata.

4 The formation of cork has resulted in barring the stoma.

5 Division of the epidermis, the origin of the phellogenetic layer.

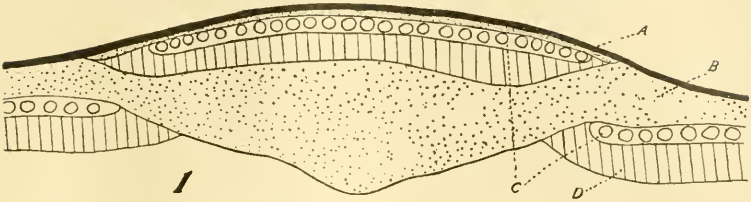
6 Stone cork, four cell layers thick, showing the pores with adjacent thin-walled cork. No pits occur in the secondarily modified wall of the outside cell in the series of stone cork cells.

7 Layers of stone cork not uniformly thickened.

8 The beginning of the formation of thick-walled cork at the margin of a diseased area.

9 Two isolated layers of stone cork separated by thin-walled cork.

10 A portion of the same as figure 1.



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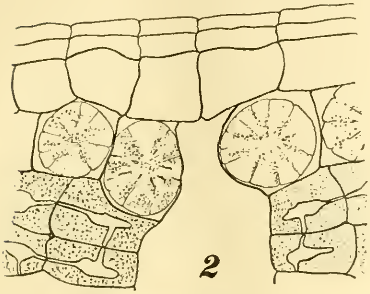

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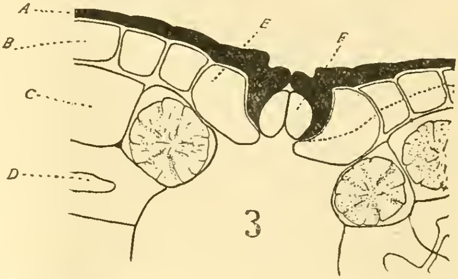

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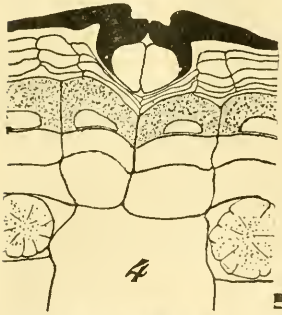

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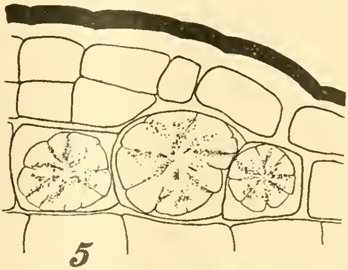

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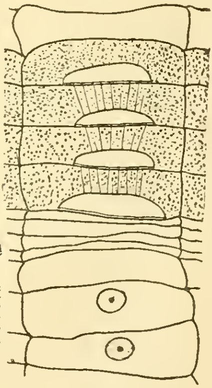

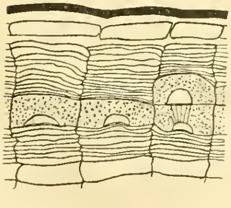

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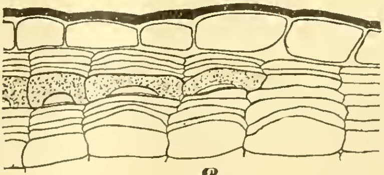

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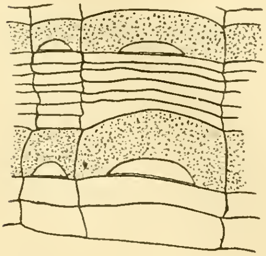

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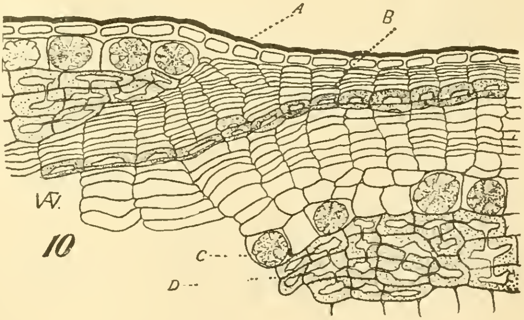

10

BOOKS AND CURRENT LITERATURE

An Intensive Study of Soil and Climate.—Kraus has added an extended paper[1] to the list of those in which he has described the vegetation and physical conditions of the vicinity of Würzburg. The keynote of this paper is found in the author's statement that "under natural conditions one may find in the smallest areas an endless diversity of chemically and physically distinct habitats." The paper is at once an elaboration of this idea, and a contribution to the precise, as distinguished from the superficial, knowledge of the relation of plants to chemically distinct soils.

The region over which Kraus has worked, in the immediate vicinity of Gambach, possesses three distinct geological formations: limestone, red sandstone, and loess, each of which has given rise to its overlying soil, with a certain amount of admixture in small areas. Determinations were made of the percentages of carbonate (mainly calcium, but partly magnesium) in the underlying rock, and in the soil at various depths, discovering a decreasing percentage from rock to soil and from deep to superficial soil. The lime content of the calcareous soils themselves was found to vary from 21 to 57 %, that of the silicious soils of the red sandstone was found to never fall below 4 %, and to rise as high as 22 %, whereas the loess soils were often free of lime. Many examples are given of the great variation of lime content in closely adjacent soils. For example, on a calcareous soil five samples were taken within a 40 cm. square which varied from 18 to 40 %. Numerous examinations were made of the earth surrounding the roots of plants, and the majority of species were found to grow in soils with lime content ranging between maximum and minimum amounts which were from 30 to 40 % apart, although the total range was higher in some plants and lower in others. A species of *Pulsatilla* was found on soils entirely lacking in lime, and on others with 54 %; while *Hippocrepis comosa* was found on soil free from lime and on soil with 69 %. A few species of plants were found which grow only on calcareous soils, but show themselves able to do with widely varying amounts of lime. Such plants as *Calluna* and *Vaccin-*

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[1] Kraus, G., Boden und Klima auf kleinstem Raum; Versuch einer exakten Behandlung des Standorts auf dem Wellenkalk. Pp. 184, pls. 7, Fischer, Jena, 1911.

ium, well known as absentees from calcareous soils, were found in soil with 3.4 % of lime; *Sarcothamnus scoparius* was the only plant found solely on soils free of lime.

These results lead us to realize the wide diversity of the percentages of line in calcareous and "non-calcareous" soils, and the ability of the generality of plants to endure wide ranges of lime content. During the growth of a single plant its root system encounters different percentages of lime at different depths, and the percentage at a given spot varies during the life of the plant. Almost the whole of the evidence regarding the rôle of soil chemistry in determining the distribution of plants, from Thurmann to the most recent writers, has been gathered by purely observational methods in which the mineralogical character of the underlying rock was the only criterion of the chemical nature of the soil. While Kraus does not compel us to discard the distinction of lime plants and silicious plants, he nevertheless makes it necessary for us to greatly broaden our conception of them, and he places future workers in this field under the necessity of using precise methods of determination of the state of the soil.

The work of Kraus on the climate of his area is also devoted to an elaboration of the differences which exist within very small space. He discusses variations of soil moisture between wet and dry periods, between north and south slopes, between bare and leaf-covered soil, as well as between different depths. Temperature is discussed chiefly in connection with the relation of air and soil temperatures, and their significance for plants, although vertical differences of temperature are also discussed, and the temperature amid the foliage of plants. Humidity and wind are also discussed, more briefly, the author having already published results on a study of the wind in this area.

Kraus's work on climate is not so thorough as that on soil, in which lies the principal value of his paper. It helps, however, to emphasize his contention regarding the differences of environmental conditions which may be found within small compass. While this contention needs little argument among those who have done outdoor instrumentation, it is nevertheless one which has not been previously made in botanical literature with such full supporting data.—F. S.

NOTES AND COMMENT

The publication of the list of doctorates for 1912 (Science, August 2, 1912) renews interest in the matter of the training and direction which a beginner in research may receive in the various schools of botany in America. The analysis of degrees given in 1911 printed in The Plant World for October, 1911, showed that twenty had been conferred in botany in that year and that nine others presented results of possible interest to botanists. The title of a thesis does not always give a reliable indication of its scope, but there appear to have been granted thirty-three degrees for botanical work in 1912, while five other titles appear which might concern botanical science in an important manner. Fourteen of the thirty-three are morphological, dealing with developmental, embryological or quantitative aspects of plants; four are taxonomic, descriptive or palaentological, eleven are physiological or genetic studies; two are descriptive ecology with which might be classed a third in comparative anatomy already credited to morphology, and two are pathological. The incidental titles are chiefly bacteriological. The full list is as follows:

Melvin Amos Brannon: The Action of Salton Sea Water on Plant Tissues.
Sophia Hennion Eckerson: A Physiological and Chemical Study of After-ripening.
Laura Campbell Gano: The Physiographic Ecology of Northern Florida.
Stella Mary Hague: A Morphological Study of *Diospyros virginiana*.
Ansel Francis Hemenway: The Phloem of Dicotyledons.
Eugene Franklin McCampbell: The Toxic and Antigenic Properties of *Bacterium welchii*.
Lester Whyland Sharp: Spermatogenesis in *Equisetum*.
Anna Morse Starr: Comparative Anatomy of Dune Plants.
Bernard Ogilvie Dodge: Methods of Culture and the Morphology of the Archicarp in certain species of the Ascobolaceae.
Winifred Josephine Robinson: A Taxonomic Study of the Pteridophyta of the Hawaiian Islands.
Mortier Franklin Barrus: The Bean Anthracnose.
Harry Oliver Buckman: Optimum and Excessive Soil Moisture in its effects upon the Soil and the Crop.
Robert James Evans: Studies in the Variation of *Stellaria media* as induced by Temperature Exposures.
Christian Nephi Jensen: Fungous Flora of the Soil.

Clyde Everett Leighty: Studies of Variation and Correlation of Oats (*Avena savita*).
Merris Mickey McCool: The Antitoxic Action of Certain Nutrient and Non-nutrient Mineral Bases with Respect to Plants.
Clyde Hadley Myers: Variation, Correlation, and Inheritance of Characters of Wheat and Peas Grown on Soils of Different Degrees of Fertility.
Harry Westfall Redfield: A Study of Hydrogen Sulphide Production by Bacteria and its Significance in the Sanitary Examination of Water.
John Edwin Turlington: The Effect on Plant Growth of Nutrients applied at Different Periods.
Rhett Youmans Winters: The Inheritance of Size of Capsules in Pepper Hybrids.
Oliver Baker Hopkins: The Carboniferous Sphenophyllales, Equisetales, and Lycopodiales of Maryland, including certain Forms from Pennsylvania and Ohio.
Willis Edgar Maneval: The Development of *Magnolia* and *Liriodendron*, including a Discussion of the Primitiveness of the Magnoliaceae.
Marion Graham Elkins: The Maturation Phases in *Smilax herbacea*.
Charley Francis Briscoe: Tubercle Bacilli in Nature.
Albert Lemuel Whiting: A Biochemical Study of Nitrogen in Certain Legumes.
Richard Hermon Williams: A Study of Protein as a Factor in the Nutrition of Swine, with Special Reference to the Distribution of the Forms of Ash and Phosphorus in the Animal Body.
Freda Marie Bachman: A Cytological Study of *Collema*.
Warner Jackson Morse: Comparative Studies of the Bacteria associated with the Blackleg Disease of Potatoes.
Thomas Harper Goodspeed: Quantitative Studies of Inheritance in *Nicotiana* Hybrids.
Walter Pearson Kelley: The Functions and Distribution of Manganese in Plants and Soils.
Henry Newell Goddard: Can Soil Fungi Assimilate Atmospheric Nitrogen?
Elizabeth Dorothy Wuist: The Morpho-physiological Life History of the Gameophyte of *Onoclea struthiopteris*.
Freda Detmers: An Ecological Study of Buckeye Lake—a Contribution to the Phytogeography of Ohio.
William Ward Browne: Acid Production by the *Bacillus coli* Group.
Caroline Anna Black: The Morphology of *Riccia frostii* Aust.
William Logan Woodburn: Spermatogenesis in certain Hepaticae.
James Ellis Gow: Embryology of the Aroids.
Fred Jay Seaver: The Hypocreales of North America.
Hally Delila Mary Jolivette: Studies on the Reaction of *Pilobolus* to Light Stimuli.

An increase of over 60 per cent in the energy devoted to botanical science can not but be gratifying to those acquainted with the demands made for men trained in some branch of the subject as teachers, and as specialists in the agricultural and other applied science practises. It is notable that with the growing interest in pathology, but few beginners find time to carry through serious investigations in this subject. It is apparent that the demand for pathologists, like that for foresters, is such that students are attracted to positions before their training has progressed so far as to enable them to undertake serious research. Practicioners are necessary, and the need for skilled experts calls strongly to the enthusiastic student, but pathology will not attain its best development until its devotees find time to carry out researches dealing with the basic phenomena with which they are concerned. It is notable also that plant geography is represented among the doctorates only by physiographic ecology and descriptive work. The broader phases of the subject however may not be attacked with profit by the student under the restricting routine which largely encompasses the candidate, except under the most enlightened guidance and with exceptional privileges as to residence and other incidentals.—D. T. M.

G. Schmid, a student of Stahl at Jena, has recently published in Flora (**104**: 335) a paper describing the results of work on the nutrition of several species of insectivorous plants. The poorly developed root system of *Drosera* and the simple types of leaf structure found in *Drosera*, *Drosophyllum*, *Dionaea* and other forms, are considered as standing in correlation with the insectivorous habit. The low photosynthetic activity found in *Drosera* and other species is accompanied by a high starch content in the cells of the mesophyll. This excess of starch disappears from the portions of the leaf, in *Pinguicula*, on which insect remains are being absorbed, due, as Schmid surmises, to the access of inorganic salts. *Drosera* is poor in potassium and phosphorus. These elements cannot be detected in the tentacles when they are at rest, but appear in quantity when digestion is going on. Insect remains appear, therefore, to be important not only as sources of nitrogenous food, but also of certain inorganic salts in which the typical substrata of insectivorous plants are known to be deficient. The clogging of leaves with starch might be quite as well attributed to the lack of the nitrogenous materials necessary for metabolism as to the lack of inorganic salts. The author has attempted no experimental work in these directions.