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Arthur Beatty,

Secretary.

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THE PERIODICITY AND DISTRIBUTION OF RADIAL GROWTH IN TREES AND THEIR RELATION TO THE DEVELOPMENT OF "ANNUAL" RINGS.

J. G. Grossenbacher,

INTRODUCTION.

The study of the so-called "annual" rings in trees has received the attention of numerous investigators during past years and still claims the interest of many. Research along that line, however, is not as active as formerly apparently owing to the general prevalence of the idea that the causes of ring formation are beyond our ability to fathom at present; although it is generally conceded that an environment resulting in discontinuous radial growth is somehow responsible for their occurrence.

In studying crown-rot of fruit trees[1] I found that radial growth and especially its distribution on trees during late summer seemed to have a relation to the occurrence of the disease. A number of more or less incidental remarks had been noted in the literature concerning irregularities in the time of commencement and closing of cambial activity, but the irregularities occurring in fruit trees during late summer and fall were found so marked that the literature was more carefully examined. The number of significant papers on the subject proved so large and the conclusions drawn so varied and contradictory that it seemed desirable to discuss radial growth and the factors thought to determine its distribution in a separate paper before writing up

[1] Crown-rot, Arsenical poisoning and winter-injury. N. Y. State Agrl. Expt. Sta. Tech. Bul. 12:367–411. 1909.
Crown-rot of fruit trees: field studies. N. Y. State Agrl. Expt. Sta. Tech. Bul. 23: 1–59. 1912.

the results obtained from a histological study of the early stages of crown-rot.

The purpose of this paper, then, is to summarize in some detail most of the important hypotheses and investigations dealing with the matter included in the title, to compare them with one another and to bring out their relation to the writer's observations. Thus collecting the widely scattered ideas and summarizing the records of research along this line, it is hoped will stimulate a wider interest in the causes of periodic growth in trees and encourage and lead to their reconsideration from a more modern or quantitative standpoint. In the main the aim is to restate the questions raised by the investigators, although sometimes in a modified form. A restudy of the structural and tension changes accompanying periodic growth may also lead to an investigation of the enzymes active during radial growth and to the effect which adverse changes of environment have upon them while in an active condition. In any case studies of this type will throw more light on the relation of a varying environment to vegetative and reproductive processes in woody plants and thereby increase the knowledge necessary for a comprehensive investigation of their diseases. Most of the diseases of trees which are of much economic importance and of most scientific interest begin in the bark, and their origin seems to have a definite relation to such radial growth and consequent bark tensions, the normal adjustment of which is interfered with by subsequent changes in the environment. Studies of that kind will also help to clarify and perhaps correct some misapprehension that may exist regarding the relation of mycology and physiology to plant pathology.

Seasonal Periodicity of Growth.

It is generally held that seasonal periodicity or the alternation of one or more growing and resting periods during the year is a more or less unalterable inheritance of perennial plants of temperate zones, but Klebs starting with his extensive investigations on the artificial control of periodicity in algae and fungi,[2] has reached a very different conclusion regarding the periodic

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[2] Klebs, G. Willkürliche Entwickelungsänderungen be Pflanzen. pp. 166. Jena, 1903.

habit of such plants.[3] He maintains that the periodic or discontinuous habit of vegetative activity in plants is due to an alternation of favorable and unfavorable seasons of the year or to a periodicity of the climate, and that it, therefore, may be made continuous by modifying the environment. From his experimental work he concludes that dormancy is due to a reduction in one or more of the factors essential for growth, such as temperature, moisture and mineral nutrients, below the required amount; and that when such conditions occur the further manufacture and accumulation of organic foods inhibits the action of the enzymes necessary for growth. A timely increase in the limiting factor is said to either prevent or terminate a period of dormancy in most cases. The reduction in the supply of mineral foods was found to be a very important factor in inducing dormancy and, therefore, raising the temperature and increasing the supply of water and mineral foods was often found to force plants into growth. Berthold[4] also concluded that a reduction in the supply of nutrient salts is the chief factor inducing a cessation of terminal growth. This same conclusion was more recently drawn by Lakon[5] who caused the buds of various deciduous trees and shrubs to open when cuttings were placed in Knop's solution. Klebs thinks that in many cases the individual periodicity of the different branches and twigs of a tropical plant are due to differences in transpiration and mineral nutrient supply of such structures. It is thought probable that there may be a periodicity in the supply of mineral nutrients in the tropics which at times becomes a limiting factor inducing partial dormancy. On the other hand Smith[6] maintained that elongation growth of various Ceylon plants is controlled chiefly by the temperature and water supply; sometimes one and then the other or perhaps both acting together as the limiting factors.

In his interesting study of the second growth occurring on

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[3] Klebs, G. Über die Rhythmik in der Entwicklung der Pflanzen. Sitzungsber. Heidelber. Akad. Wiss. Math. Naturw. Klass. 23. 1911. pp. 84.

[4] Berthold, G. D. W. Untersuchungen zur Physiologie der pflanzlichen Organization. 2:131–257. 1904.

[5] Lakon, G. Die Beeinflussung der Winterruhe der Holzgewächse durch die Nährsalze. Ein neues Frühtreibenverfahren. Zeit. Bot. 4:561–82. 1912.

[6] Smith, A. M. On the application of the theory of the limiting factors to measurements and observations of growth in Ceylon. Ann. Roy. Bot. Gard. Peradeniya. 3:303–75. 1906.

trees Späth[7] comes to still another conclusion. According to him the occurrence of the June elongation-growth which makes its appearance fairly regularly on vigorous young trees of oak and beech, is not determined by the environment but follows the close of the spring elongation period after a fairly definite interval of time, and may even develo pduring a drought or while conditions are extremely unfavorable for growth. In Quercus the resting period between the spring and June growth was from 30 to 40 days and in Fagus from 15 to 20 days. It is said to last 9 to 16 days in the former and 13 to 24 days in the latter. The length of these second shoots is thought to depend chiefly upon the amount of available water and is usually but not always less than that of spring shoots. The species with the June-elongation habit have a short but very active spring-growth period as compared with those not having the June growth. It was found impossible to prevent the June elongation growth by reducing the food and water supply and by lowering the temperature, nor could it be made to continue beyond the ordinary period by supplying heat, moisture and food conditions favorable for growth.

Späth also found that the second growth is made up of three types. In one kind the axillary buds of an elongating shoot develop into branches before they are fully formed. This happens in Salix, Populus, Taxus, Buxus, Prunus, Pyrus, and is called sylleptic growth. In the second type known as June growth (Johannestrieb) the buds are fully formed before they open after the termination of the spring elongation growth. The third type is called proleptic growth and is said to develop at any time during summer from buds which normally would not have opened until the following spring but which open early owing to wound or some other strong environmental stimulus.

Neither sylleptic nor June elongation-growth was said to have a zonation effect upon radial growth while the production of proleptic shoots practically always resulted in more or less distinct zonation of the radial growth. This was shown during their development by the wood cells produced being wider than those differentiated just before the new shoots appeared.

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[7] **Späth, H. L. Der Johannistrieb. Ein Beitrag zur Kenntniss der Periodizität und Jahresringbildung sommergrüner Holzgewächse. Berlin, 1912. pp. 91.**

The Beginning and Duration of Radial Growth.

Observations and statements regarding the commencement of cambial activity or radial growth in spring are many but no positive conclusion can as yet be drawn as to just where on any particular species of tree it will begin one season after another. In fact it seems to differ considerably for individuals of the same species.

According to Strasburger[8] in pines as well as in Picea, as many as five layers of tracheids had been formed from the cambium in one-year shoots and considerable elongation growth had occurred by the first of May, while at the bases and on the trunks of eight-year old branches the cambium was still inactive. In case of *Robinia Pseudacacia* and some other species, however, radial growth was found to begin first on the trunk. But in general cambial activity is said to begin in one-year shoots just back of the unfolding buds and to proceed downward to the larger branches and trunks on which it usually begins uniformly and at about the same time from top to bottom. He found that the cambium gives rise chiefly or almost exclusive to wood cells[9] in spring, and as the vegetative season advances, the production of phloem increases while that of wood cells decreases. In trees of our zone wood formation is said to cease by mid-August while that of the phloem continues practically up to the end of the vegetative season. Wood cells are therefore usually matured before winter but phloem cells sometimes enter the dormant season in an immature condition.

Pfeffer[10] also says that "the secondary growth of xylem in trees begins and ends sooner than that of the phloem."

Hartig[11] states that although no growth had occurred on April 15 on any of the sixteen-year-old trees under observation, by May 5 the new radial growth in oak was about equal on all parts of the trunk but that none had occurred underground; while in maple, though the buds were farther advanced than in oak, the growth as yet was confined chiefly to the one-year shoots.

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[8] Strasburger, E. Ueber den Bau und die Verrichtungen der Leitungsbahnen in den Pflanzen. Histologische Beiträge 3:494. 1891.

[9] l. c. p. 282.

[10] Pfeffer-Ewart. The Physiology of Plants. 2nd revised Ed. 2:207. 1903.

[11] Hartig, Th. Beiträge zur physiologischen Forst-Botanik. Allgem. Forst-u. Jagd-Zeit. 1857: 281–96. 1857.

On pine and larch the greatest growth had occurred at the base of the trunks. By August 19 radial growth had ceased on above-ground parts of broad-leaved trees, only a small amount had occurred on the lateral roots and none on the fibrous roots. In conifers radial growth was not entirely completed on aërial parts and the roots were in about the same condition as those of broad-leaved trees. In oak and maple radial growth on the fibrous roots began about the 1st of August, in pine about the 1st of September, in larch about mid-September. Hastings[12] found that radial growth started first back of opening terminal buds in broad-leaved trees and proceeded basad. By the time the five to six-year branches were producing new wood radial growth had become general all over the trees. In case of pine radial growth commenced on the two to three-year old portions of branches and apparently before the buds opened. It was thought that perhaps growth started on two-year branches in pine because leaves are retained two years, for it was noted that in the hemlock, where the leaves are retained six to seven years, radial growth seemed to have started first on six-year-old branches, while in the bald sypress radial growth started first just back of the opening terminal buds as in broad-leaved trees. On the other hand Knudson[13] reports that radial growth begins on young trees of the American larch in the fourth to six-year-old branches. He holds that the cambium first gives rise to phloem cells in spring and that wood cells are developed later though his counts show only a few cells. The branches showing the first radial growth were found in the middle region of the tree. Here growth began at the apexes while in the trunk xylem formation is said to start near the middle. Darkened bark, owing to its heat absorbing qualities, is thought to induce early growth.

According to Goff[14] spring growth begins in many plants on their roots. From his examinations in late March he reports that the roots of *Ribes vulgare* had elongated as much as 7.5 cm. (3 inches) before aërial growth had begun. Of the following

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[12] Hastings, G. T. When increase in thickness begins in our trees. Plant World. 3:113–16. 1900. Sc. 12:585–86. 1900.

[13] Knudson, L. Observations on the inception, season and duration of cambium development in the American larch. Bul. Torr. Bot. Club. 40:271–93. 1913.

[14] Goff, E. S. The resumption of root growth in spring. Wisc. Agrl. Expt. Sta. Ann. Rpt. 15:220–28. 1898.

species he says that root growth had also "started more or less in advance of the buds:" *Picea excelsa, P. alba, P. pungens, Pseudotsuga Douglasii, Abies concolor, Thuja occidentalis, Pinus sylvestris, Tsuga canadensis, Tamarix amurensis, Acer saccharinum, Pyrus Malus, P. Communis, Prunus cerasus, P. virginiana, Betula alba, Morus alba, Cornus stolonifer, Eleagnus hortensis, Ribes nigrum* and *R. oxyacanthoides.* When these observations are compared with those of von Mohl[15] who found that, though radial growth in conifers has practically ceased by winter and that in deciduous trees it usually has not, it seems likely that Goff overlooked the possibility that portions he held to be new spring growth may have been very late growth of the preceding fall. Hartig[16] found that the roots of various forest and fruit trees had ceased radial growth in January, as judged by the thickness of the new ring and by the presence of starch in all of the ray cells of the cambial region. Russow[17] made similar observations in regard to both forest and fruit trees. Hartig notes an exception in the case of a species of willow where radial growth of the roots had not been completed as shown by the thinness of the ring as well as by the absence of starch in the ray cells of the cambial region. Resa[18] also made some observations which support Goff in some cases at least. He found that the roots of Picea and Fagus ceased growth in November and recommenced in February and March, while in case of *Aesculus Hippocastanum* and Tilia root growth ceased in October and recommenced in December or later. In *Alnus glutinosa* root growth began in October and continued practically through the winter except when the ground was frozen. Root growth began in late May in *Acer campestre* and in June in *Quercus Robur.* It is not usually considered that such enormous variations occur in the root growth of our trees and shrubs and for want of more detailed information it seems necessary to admit that at least in some

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[15] von Mohl, H. Einige anatomische und physiologische Bemerkungen über das Holz der Baumwurzeln. Bot. Zeit. 20:225–30; 233–39; 268–78; 281–87; 289–95; 313–19; 321–27. 1862.

[16] Hartig, Th. Ueber die Zeit des Zuwachses der Bäume. Bot. Zeit. 21:288–89. 1863.

[17] Russow, E. Über den Inhalt der parenchymentischen Elemente der Rinde vor und während des Knospenaustriebes und Beginns der Cambiumthätigkeit in Stamm und Wurzel der einheimischen Lignosen. Stizungsber. Naturforscher-Ges. 6:386–88. 1884.

[18] Resa, F. Ueber die Periode der Wurzelbildung. Inaug. Dissert. Bonn. 1877. pp. 37.

cases root growth may precede the growth of aërial parts of trees in spring.

Schwarz[19] found that radial growth may start in spring in various parts of trees depending on the environment. In case of a much shaded or overtopped tree it was found that radial growth had begun at the base, while half way up the trunk the cambium was still dormant. In another instance 43% of the ring had formed at the base of a tree by July 27, while 5.5 m. up the trunk no growth had yet occurred. These irregularities are held not to be attributable to differences in temperature occurring at the different regions. Mechanical stimuli to be discussed later are held to be the instigators and distributors of radial growth.

THE RELATION OF FOOD DISTRIBUTION AND THE PRESENCE OF ELONGATING STRUCTURES TO THE OCCURRENCE OF RADIAL GROWTH.

It is of interest to know definitely what relation exists between the occurrence of radial growth and elongation growth or whether both are simply dependent upon the presence of certain unknown amounts of elaborated and inorganic foods in connection with the enzymes that may be involved in food transformations and growth. The experiments of Jost[20] indicate that a casual relation exists between radial growth and some phases of elongation growth or the presence of unfolding buds, since on the removal of the buds from seedling beans radial growth practically ceased although elongation might continue. Starch was present in abundance and increased after the operation yet cambial activity remained in abeyance. All the elongation buds were removed from several years growth of branches of *Pinus Laricio* on March 8 while the dwarf branches and their leaves were allowed to stay. The dwarf branches which were nearly terminal then developed elongation buds. By the end of May but few tracheids had developed in the decapitated branches while in normal branches a new layer of about twelve tracheids was present, and they had become lignified. A month later the mutilated

[19] Schwarz, F. Physiologische Untersuchungen über Dickenwachstum und Holzqualität von Pinus silvestris. Berlin. 1899. pp. 371.

[20] Jost, L. Ueber Dickenwachstum und Jahresringbildung. Bot. Zeit. 49:485–95; 501–10; 525–31; 541–47; 557–63; 573–79; 589–96; 605–11; 625–30. 1891.

branches had a layer of tracheids not to exceed five or six while a branch from which all dwarf-branches or assimilating leaves had been removed on March 8 but on which the terminal buds had been left, had developed a layer of eighteen to twenty tracheids.

In another experiment Jost removed buds from branches in early May. When examined in fall it was found that at a certain point or line in the year's growth the radial diameter of the tracheids was suddenly reduced and then increased again, thus indicating the time when the buds were removed. The doubling effect on the wood ring resulting from the removal of the leaves at a certain time, has since been investigated by Kühne as noted below.

In a later paper Jost[21] reports some further experiments along this line. Defoliated pine branches were found to undergo normal radial growth provided the terminal buds are not removed, though they may be kept in the dark; while when the last grown leaves and the terminal buds were removed very little or no radial growth occurred. Practically the same results were obtained following a similar experiment with Rhododendron. Holes were bored into the trunks of various trees in late September and covered to prevent evaporation. By mid-October callus formation had occurred in all but Tilia, even though general growth had ceased. That is, it appears that although cambial activity is usually started by leaf or shoot elongation wounding may also induce it, and that not the availability of food but a distal connection with some growing leaf-structures or buds is necessary for the occurrence of radial growth. This same phenomonon is also indicated by the results of an experiment wlth Periploca. Although this plant has bicollateral bundles, removing a girdle of bark prevented radial growth on the basad side of the girdle. Nördlinger[22] had noted that in case of most trees from which the branches are removed in winter practically no radial growth occurred during the following vegetative season although in some instances slight growth resulted.

[21] Jost, L. Ueber Beziehungen zwischen der Blattentwicklung und der Gefassbildung in der Pflanze. Bot. Zeit. 51:89–138. 1893.

[22] Nördinger, H. Der Holzring als Grundlage des Baumkörpers. Stuttgart. 1871. pp. 47.

[23] Vöchting, H. Zur experimentellen Anatomie. Nachrichten Kgl. Ges. Wiss. Göttingen. 1902:278–83. 1902.

Vöchting[23] also found that decapitating herbaceous plants resulted in the cessation of radial growth of the stele though increase in diameter may result from the growth of the pith and cortical parenchyma. After such decapitated plants were budded cambial activity was resumed.

Reiche[24] also notes regarding trees of Chili that radial growth begins after the buds burst and that it does not occur unless bud development precedes it.

The more detailed experiments by Lutz [25] also give support to Jost's conclusions regarding the relation of growing leaves or buds to radial growth, and they show besides that other things being equal the distribution of food may also be a determining factor in the occurrence of radial growth. All the buds and leaves of six to ten-year old trees of *Fagus silvatica* and some of *Pinus silvestris* five to seventeen years of age were removed at intervals from spring through the summer and the amounts of reserve starch and growth were determined. The buds were removed on March 20 from a Fagus which was about a meter high. Branches were examined for the distribution of starch and for radial growth on June 15, July 1, 15 and 30, August 10 and 20, on the 10th of September, October and November, as well as December 5 and 23. The adventitious buds were removed but continued to reappear, some large ones being removed on October 10. Only minor fluctuations in the starch content of the pith rays, wood and bark of the branches were noted through the summer with an almost entire disappearance of starch in December. The branches remained healthy-looking but no radial growth resulted. Similar trees were defoliated on May 20, June 15, July 1, 15 and 30, and August 28 respectively, and also freed of buds at intervals during the remainder of the growing season. Branches of these trees were also examined on the above dates. In the tree defoliated on May 20 no starch was found in the branches aside from traces which occurred in the pith and broad rays during midsummer, and even that had disappeared by August 20. Only a small amount of radial growth took place which had all occurred by July. On October 30 the stem or trunk was found to contain considerable starch at the ground or

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[24] Reiche, K. Zur Kentniss der Lebensthätigkeit einiger chilenischen Holzgewächse. Jahrb. Wiss. Bot. 30:81–115. 1897.

[25] Lutz, K. G. Beiträge zur Physiologie der Holzgewächse. Beiträge Wiss. Bot. 1:1–8. 1897.

crown in the pith, rays, and bark yet no radial growth had occurred at that point, while, 20 cm. above ground where no starch was present, about 4% of the normal amount of radial growth had occurred. The thickness of the new growth in the trunk increased upward until at 75 cm. above ground a maximum of 30% of the normal amount had occurred although no starch was present there. A little starch was present in the main root near the crown but none occurred in the laterals and no radial growth had occurred in them.

Corresponding results were also obtained with the other trees. The starch content and radial growth were found to have increased in each case, until, in the tree defoliated on August 28, the amounts of both starch and growth were normal. It should be noted, however, in cases where defoliation induced much reduction of food and growth of the trunks, that a radial growth maximum usually occurred about 75 to 80 cm. above ground, such as given above in detail. The year's growth of full-leaved, young trees was found to be in excess of that occurring in preceding years and their starch content was very high throughout the summer.

Five young trees of *Pinus silvestris* were used in similar experiments; one being defoliated on each of the following dates: March 20, May 20, June 15, July 1, and August 30. The buds which had been left on the tree defoliated March 20 had burst by May 20, although the needles had not reached full size. On July 1 and 30 some more buds had burst and begun to develop needles. On June 15 small amounts of starch were present in the branches. On August 20 no starch was present and only from 4 to 20% of normal radial growth was found. On October 10, when the tree was taken out traces of starch were still present in the base or crown of the trunk but none occurred in the roots. The roots had died and their bark had become loose and infested with nematodes. Brown spots occurred on the bark of the stem and the twigs were being eaten by insects. The new growth was very irregularly distributed over the stem. Around the circumference just above the ground growth varied from none to 8% of the normal thickness and from this point upward the variations were equally as marked.

In the tree defoliated on May 20 no starch was found during the summer, yet from 10 to 60% of the normal increase in thickness had occurred. In the remaining three trees traces of starch were present which soon disappeared. The radial growth ranged from 25% to normal. The tree defoliated June 15 was dead by October and the one defoliated in August by the following May.

The stems of the first four and of some untreated young pines were cut in 15 to 30 cm. pieces in October and by December the bark on the treated-tree pieces was found to have loosened especially where considerable radial growth had occurred. The bark had split and was shrunken both in length and circumference; while that on the pieces from untreated trees adhered firmly to the wood. In December pieces were also cut from the branches of the last treated tree, the bark of which had lost its turgidity after the operation but regained it again. A discolored circle was found in the cambial region. Groups of undifferentiated wood cells had been ruptured or broken down and were discolored.

In his researches on the reserve food of trees du Sablon[26] found that the carbohydrate content underwent farily definite seasonal changes which apparently occurred irrespective of the weather. On March 17 the roots of pear trees contained much more sugar and very much more starch than the stems and the total carbohydrate content of roots was also higher. In stems of chestnut trees the carbohydrate content reached a maximum in October and a minimum in May, while in roots the maximum came in September and the minimum in May. In case of quince the maximum in both root and stem was found in January with a minimum in stems in May and in roots in June. In peach the minimum in both root and stem came in May and the maximum in the stem in July and in roots in November. In willow both stem and roots were found to have a minimum of carbohydrates in April and a maximum in October, but both the maximum and minimum were more extreme in the roots. In the case of raspberry bushes the roots had a minimum in April and a maximum in October, while in the biennial stems a high carbohydrate content was maintained during the first summer with a maximum in October, followed by a slight depression and subsequently a lesser maximum in the second April. Afterwards a fairly constant

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[26] du Sablon, Leclerc. Recherches physiologiques sur les matières de reserves des arbres. Rev. Gen. Bot. 16:339–68; 386–401. 1904.

decrease in the carbohydrates occurred until the end of the stem's life.

The observations by Fabricius[27] on the distribution of food in large spruce trees throughout the entire year seems also to throw some light on the possible relation this may have to the inception of radial growth in spring. The first tree was cut in February. It was 25 m. high, had 68 growth rings at the base and its lowest branches were 14 m. above the ground. The bark of the stem 30 cm. above ground had considerable starch in the medullary rays, and less in the parenchyma. The older phelloderm and ray cells contained less starch than the younger ones. Practically the same distribution of starch obtained in the entire bark of the trunk up to the first branches. From the branches upward the starch gradually increased to a maximum at 21 m. and diminished again near the distal tip where but little was present. The twenty-five outer rings in the lower part of the trunk had live, starch-bearing wood-rays and gum-canal cells and only the outer half of the youngest wood-ring contained no starch. Fifteen meters above ground where the stem had 36 rings only 19 contained live cells and at 18 m. about a tenth of the ray cells were alive and starch bearing in the innermost of the 21 rings. In the one-year shoot only about half of the pith contained starch. The distribution of the fats was similar to that of the starch but it was much less in amount except in the youngest twigs. The decrease of reserve food near the distal portions was thought to be due to a loss through respiration during winter.

The starch content of small roots was slight but usually increased with their diameter up to 1 to 2 mm. An excentric root having 55 rings on one side and 37 on the other contained starch in the outer 20 rings of the thicker side and in the outer 15 of the thinner. Only the roots over 2.5 cm. in diameter contained fats. In some cases excentric roots were found to have a difference of as much as 50 growth rings between the broad and narrow sides, yet the cambium on the thinner side was normal, although it was evident that it often remained inactive during several years. The relative amounts of starch stored on the different sides of an excentric root was proportional to the amount of growth on any side.

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[27] Fabricius, L. Untersuchungen über den Stärke-und Fettgehalt der Fichte auf der oberbayerischen Hochebene. Naturw. Zeit. Land-u. Forstw. 3:137–76. 1905.

A tree with 82 rings at its base and 22 m. high was cut in March. The bark was fairly rich in starch from the ground up. The 32 outer rings of wood contained starch. At the first branches 12 m. above ground, where the stem had thirty rings, only the fifteen outer rings were alive and starch bearing. At a height of 18 m. eleven or twelve of the fourteen rings present contained starch. Considerable starch occurred in the wood at the tree's base and decreased rapidly upward to a minimum about 3 m. above ground, above which it gradually increased again to a maximum just below the branches. From this point upward a decrease occurred which reached a second minimum 18 m. above ground, and was followed by a second increase upward to a maximum at the point where the stem had but six wood rings. No fats could be found in the bark and very little in the wood. Apparently fats had been changed to starch. More starch was present in the small branches of this tree than of the one cut in February. Both the wood and bark of the roots contained considerable starch except the youngest phloem cells which were devoid of it. In excentric roots the starch distribution was similar to that found in the former tree.

Another tree which was much like the one cut in March as to size, age, etc., was cut in late April. Its bark was rich in starch with the exception of the phloem about 8 m. above ground where none occurred. The reduction in the number of live, starch-bearing wood rings from below upward was about the same as in the other cases. The wood rays near the cambium were devoid of starch. A slight amount of fat was present in the bark, while that of the wood increased from a small amount at the base of the tree upward to a maximum in the smallest twigs where it exceeded the starch. In this case a starch maximum occurred also at the base of the trunk, while in the branch bearing part of the stem the starch was evidently being dissolved from the cambium inward and in increasing extent upward. Fats were abundant throughout the trunks and also present in the wood of the larger roots but absent from the bark of roots. But very little starch was present in the wood-rays at the base of the trunk and the season's growth of wood was devoid of starch, while the previous year's growth was almost free of it in mid-June. From this region upward starch-free peripheral wood increased up to the first branches, where it included the outer four rings. In the branch-bearing portion of the stem the outer rings again showed some starch. All the wood was rich in fats which usually exceeded the starch present. In the phloem only the youngest cells had appreciable amounts of fat. That is, in mid-July more fat and less starch is present in spruce than in June.

Very little starch occurred in the one-year roots but it increased in amount toward the thicker roots so that in four-year roots as much starch was present as there had been in the trees cut before. The bark also contained much starch but very little fat. No fat was present in the wood of the smallest roots but it occurred in the larger ones and increased upward. The new elongation growth of the roots and the bark on the thin ones, as well as the young wood and phloem, were devoid of starch although considerable was present in the large roots. Fat occurred in the root wood and in occasional places in the bark.

By the last of August an additional reduction had occurred in the fat content of the bark and the starch in the bark had also decreased from the ground upward while nearly the entire wood cylinder had become practically starch-free. The bark of the larger roots contained considerable starch but it was irregularly distributed. In the youngest phloem it was absent. The wood-rays in the larger roots and stumps had fairly large amounts of fat present. In general it may be said that the starch decreased in the aërial parts and increased underground since last examined in July. The transition occurring at the crown or stump where starch was less and fat more abundant than earlier in the summer.

On September 25 the bark of the stem contained considerable starch but it was present in decreasing amount from the first branches upward to practically none in the season's growth of shoots. Nearly the entire wood cylinder was devoid of starch excepting a small amount at its base or crown and in the inner living rings. Both bark and wood were rich in fats especially in the rays. The maximum fat content occurred about 3 m. above ground where starch was practically absent. All except the thin roots were comparatively rich in starch. In the wood starch increased toward the stump. The larger roots also contained considerable fat while the small ones had none.

On October 28 the bark of the stem near the ground contained very large quantities of starch, which gradually diminished upward to the branches where it increased again but none was present in the season's shoots. In the wood of the stump the starch was also abundant especially in the rays. It decreased upward to the branches and in the season's shoots only a little was present near the pith. The fat content of the bark increased from the ground upward but beyond the four-year-old branches there was but little fat present. In general less fat than starch was present in the wood of the stem but it gradually increased from the ground up to the branches.

A marked starch increase in the wood since September was evident while the fat content had not been correspondingly reduced, in fact it was considerable in the branch-bearing part of the trunk. The distribution and relative amounts of reserve food was very similar to that found on the preceding February. It is therefore thought evident that starch does not diminish early in the dormant season and that it is retained as starch throughout winter.

The bark of the roots had an increasing amount of starch toward the stump until a maximum was reached in roots 2 to 3 cm. in diameter after which it diminished. The wood contained considerable starch in as many as thirty of the outer rings near the stump and then the number of starch bearing rings decreased peripherally as it did in the stem from the ground upward. In an excentric root with a radius of 44 mm. on one side and of 7 mm. on the other twenty rings contained starch on the thicker side and ten on the other. The thicker side had 70 rings and the opposite side 20 showing that during 50 growing seasons no radial growth had occurred on the thinner side. The roots contained considerable fat which diminished toward the stump.

In this case as well as in the tree cut in February the youngest phloem and the included portions of the phloem rays besides the outer cortex contained very little starch while that portion of the bark between them contained much starch. Fabricius thinks that the characteristic browning of the inner phloem so commonly noted in late winter and spring, which has been attributed to the action of atmospheric electricity by Tebeuf,[28] probably has a relation to this distribution of reserve food in the bark.

[28] Tubeuf, K. von. Beobachtung über elektrische Erscheinungen im Walde.
Naturw. Zeit. Land-u. Forstw. 3:493–507. 1905.

From these observations on reserve food distribution in large trees it seems evident that most of the starch is converted to fat during spring and early summer, and reconverted to starch again beginning in late September, so that the smaller portion of reserve food passes the winter as fat. Fischer's[29] observations do not agree with those of Fabricius but, since the former based practically all his conclusions on specimens from stems ten years old or less his conclusions are not surprising.

According to Fabricius there is a general increase of starch also in spring but it is of short duration. By April 22 it had largely disappeared from both sides of the cambial region and more especially toward the top of the tree, i. e., apparently in proportion to cambial activity. At the same time the process of converting the reserve starch in the older rings to fat (which continues all summer) is also going on. The redeposition of reserve food is begun in the bark in the form of starch. In the wood this process does not begin till about the last of September and not until October is the fat in the wood converted into starch. The fat in the bark is used up during summer and, from the peripheral shoots downward, followed by a redeposition of starch as the second growth is finished in late summer. Elongation growth of roots is said to occur chiefly in June and July and again to a slight extent in October. During those periods they contained considerable fat which afterwards disappeared.

This series of examinations has shown that the fat content of roots is practically proportional to the amount of elongation growth in progress and that when this growth ceases very little or no fat is present, i. e., a causal relation seems to exist between fat content and elongation growth. It is thought that perhaps the growing tip secrets an enzyme which is carried up the root by the "transpiration current," and which converts starch to fats. After the cessation of growth the fats are again changed to starch.

A more recent contribution to this discussion is by Preston and Phillips,[30] but it also is based chiefly on determinations made on young trees. The study covered the period from October to

[29] Fischer, A. Beiträge zur Physiologie der Holzgewächse. Jahrb. Wiss. Bot. 22:73–160. 1891.
[30] Preston, J. F., and Phillips, F. J. Seasonal variation in the food reserve of trees. Forest Quarterly 9:232–43. 1911.

June and included both hard and soft wood trees. It was found that all starch disappeared in winter from *Populus deltoides, Salix alba* and *Juniperus virginiana,* while *Quercus rubra, Ulmus americana, Acer saccharum* and *Juglans nigra* retained considerable starch in the wood through the winter. *Tilia americana* underwent a starch reduction but retained some in the phloem, medullary rays, and xylem, while *Carya glabra* lost its starch in small stems but retained about a fourth of it in larger stems.

None of these trees except Carya showed a reduction of starch in the roots during winter. Large amounts of sugar were found present only in spring as the buds were unfolding. The trees tested had a maximum fat content in late fall and a minimum in spring. These tests seem to show that broad-leaved hard wood trees cannot be called starch trees nor those with soft wood fat trees, as had been done by Fischer.

Niklewski[31] concluded from his study that the starch conversion in soft wood trees like Tilia, Betula, etc. is practically complete on the approach of winter, while in hardwood trees like Prunus and Syringa it is only partial. It was found that fats are more abundant in winter and also that a rise in temperature increased the amount.

According to Wotczal[32] starch transformation begins in spring in the distal parts of shoots and roots and proceeds towards the older portions of the tree, although it starts later in roots than in the shoots. But normally these two waves of starch transformation starting in the roots and shoots do not encounter one another, and in this way a starch residue remains in the older wood and in the region of the root-crown. The deposition of starch then occurs in the reverse manner throughout the tree, i. e. it begins in the oldest parts and around the root-crown and proceeds wave-like toward the distal ends of the shoots and roots.

The work by Fabricius reviewed above shows that remarkable and apparently wave-like progressive changes occur in the state and distribution of reserve foods in trees and that maxima and minima of the different types occur in certain parts at rather definite periods of the seasonal history. The above cited experi-

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[31] Niklewski, B. Untersuchungen über die Umwandlung einiger stickstoffreier Reservestoffe während der Winterperiode der Bäume. Beihefte Bot. Centralbl. 19 Abt. 1:68–117. 1906.

[32] Wotczal, E. Die Stärkeablagerung in den Holzgewächsen. Bot. Centralbl. 41:99–100. 1890.

ments by Lutz show in addition that food distribution in stems is related to the source and amount of elaborated food descending from the leaves although such factors do not seem to prevent the eventual regional distribution so strongly brought out by the observations of Fabricius, except in cases where the supply is very limited and apparently all used up or deposited on its way down the tree. At any rate, in such instances too little reaches the lower part of the trunk and roots to permit the occurrence of radial growth in those regions. Some recent defoliation experiments by Kühns[33] show that the radial growth occurring after defoliation usually does not extend to the base of the stem and, therefore, results in an incomplete double ring. In this case as in those cited by Hartig, Rubner, etc., the conclusion seems warranted that radial growth was omitted on the lower part of the trunk and roots chiefly because the downward stream of elaborated food is used up before reaching that part of the trunk. When the growth of excentric roots and an irregular distribution of radial growth at any given circumference of a tree-trunk, as noted by Lutz, are considered in relation to the occurrence of reserve food, the problem becomes more complex. Such cases make it necessary either to assume that elaborated food is thus irregularly distributed in a tree or else that other factors are involved in the distribution of radial growth. Fabricius found that food is stored in a larger number of rings on the thicker side of an eccentric root, but that does not necessarily mean that the oldest starch-bearing rings on that side are any older than the oldest starch-bearing ones on the thinner side since rings are often entirely omitted on the narrower side. It is at least possible that radial growth begins in spring in that portion of a tree in which the greatest amount of food is stored and in view of the fairly well established fact that growth continues longest in fall in such regions of maximum food content this possibility is somewhat emphasized. Perhaps it might be of interest first to consider the causes of excentric growth as far as they have been determined before taking up the factors which have been advanced by several authors as the cause not only of the distribution of reserve foods but of the general form of tree trunks.

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[33] Kühns, R. Die Verdoppelung des Jahresringes durch künstliche Entlaubung. Biblio. Bot. 70:1–53. 1910.

THE CAUSES AND THE OCCURRENCE OF EXCENTRIC RADIAL GROWTH.

In a study of the distribution of excentric radial growth on trees it is well to note that excentricity may conceivably come about in one or more of four ways and that in a sense such an uneven growth of a stem at any height corresponds to the wave-like uneven distribution at different heights of a tree. The four ordinary ways excentric stems may be built up are (1) by the entire omission of radial growth in a part of the circumference, (2) by the unequal rate of growth on different sides of stems, (3) by the entire omission of summer growth on one side and, (4) by the omission of spring growth on a part of the circumference and its occurrence at other places. In looking over papers on excentric stems, etc., it is sometimes difficult to determine to which of the four classes the case under consideration belongs but usually that is apparent.

Gravity and other factors of the environment as well as the anatomic or physiologic characteristics of a species seem to be the causes of excentric radial growth but as yet the matter is not fully understood. That a difference may be found in trees of different groups in regard to excentric growth, when subjected to the same environment, is shown by some observations by Nördlinger.[34] He cites an instance in which saplings of conifers, beech, and oak had been bent over by the heavy snows of 1868 and afterwards grew in slanting positions. Three years later sections taken at any point of the stems showed that pine, spruce, and larch had developed three excentric rings with the larger radius below while on the oaks and beeches the three last rings were thicker above. In one spruce only one very narrow ring had been laid down on the upper side while the other rings had been wholly omitted on that side. In both oak and beech radial growth had been extremely slight on the under side during the three years. This shows that different trees subjected to the same environment may respond differently. That is, the specific characteristics of a plant to a certain extent determine the manner of response to the environment.

Müller's[35] observations seem to indicate that if excentric

[34] l. c.

[35] Müller, N. J. C. Beiträge zur Entwicklungseschichte der Baumkrone. Bot. Untersuchungen 1:512–24. 1877. Heidelberg.

growth is due to the environment the branches on the upper and lower parts of the same tree must be dominated by different factors. On measuring the cross sections of 100 large horizontal branches of beech trees he found that of those arising on the stems between eight and fifteen meters above ground 36% were epinastic, 60% hyponastic and 4% of equal radius above and below; of those arising between fifteen and twenty meters above ground 36% were epi—and 39% hyponastic and 24% had equal radii above and below; of those taken twenty to twenty-four meters above ground 64% were epi—and 28% hyponastic, with only 7% having equal radii above and below.

This opened up a phase of the problem, which is often left out of consideration. It shows that the branches of some trees are chiefly hyponastic on the lower part of trunks while they may be predominately epinastic in the upper regions. From his tabulated data the unmentioned and highly interesting fact may also be gleaned that, of the 100 branches measured, 47 had the greatest diameter in the horizontal plane and only 28 had the greatest diameter in the direction of gravity, while the other 25 were isodiametric. Although no special attention was directed to these facts by Müller he apparently was fully aware of them for he concluded that gravity is not a factor in the distribution of excentric radial growth, but that its distribution depends upon illumination and the relative proximity to the channels of most direct or greatest water and food conductance. Wiesner[36] who has given this problem much attention, says that all inclined stems of conifers are hyponastic or what he calls hypotrophic, and that those of broad-leaved trees with little or no anisophylly become first epinastic or epitrophic and eventually often become greatly hyponastic, while species with marked anisophylly are first hypotrophic and subsequently become epitrophic, and finally hypotrophic again. He maintained that excentric or heterotrophic radial growth of a branch is due to its position both in relation to gravity and to the axis from which it arises. On the other hand Gabnay[37] concludes that the difference in the specific gravity of the elaborated food or of the cell content and the degree of regenerative power possessed by the different classes of

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[36] Wiesner, J. Ueber das ungleichseitige Dickenwachsthum des Holzkörpers in Folge der Lage. Ber. Deut. Bot. Ges. 10:605–10. 1892.

[37] Gabnay, F. Die Excentrizität der Bäume. Just's Bot. Jahresber. 20:100. 1894.

trees are the factors determining whether excentric growth shall be epi– or hypotrophic. The specific gravity of the elaborated food of conifers was found appreciably greater than that of broad-leaved trees. The regenerative power of a tree is said to be inversely proportional to the specific gravity of its elaborated food and it is held that the greater the regenerative power of a tree the more epitrophic it is, while the lower its regenerative power the more hypotrophic.

From his observations on the influence of the environment on radial growth Kny[38] concludes that the excentricity of horizontal branches is not only a reaction to gravity but that it is also influenced by the relative illumination, transverse bark tension, etc., as well as by some unknown factors. In some plants the greatest thickness of one wood ring is on the lower side of a branch while subsequent rings may be thicker above. The branches of most of the broad-leaved woody plants were found to have the upper half of the wood cylinder of greater thickness than the lower, but quite a number of exceptions were also noted, e. g. Tilia, Cydonia, Fraxinus, Gleditschia, Corylus and Alnus. The branches of conifers on the other hand are thickened in excess chiefly on the lower side. In general it was found that one type of excentricity is characteristic of certain natural groups of plants, but isolated exceptions were often noted indicating that gravity plays a minor part in the distribution of radial growth. The upper side of branches is subject to greater variations of light, temperature and moisture than the lower and it was thought that perhaps bark tension might be less on the upper side owing to the greater distension of the bark on that side by the variations of the temperature; yet since the results may be just opposite in neighboring trees of different groups having the same environment no conclusions were thought admissible. It was observed that, owing to the fact that all leaves and buds attached to the under side of a lateral branch develop and grow most strongly, the axis is usually thicker on the lower side during the first year, while in subsequent years the branches on the upper side of a horizontal branch grow more rapidly than those on the lower and thus result in changing hyponastic to epinastic branches. A case is cited where the stems of *Ficus stipulata*

[38] Kny, L. Ueber das Dickenwachsthum des Holzkoerpers in seiner Abhaengigkeit von aeussern Einfluesen. pp. 136. Berlin 1882.

clambering up vertical walls were found to have both the wood and phloem portions of the bundles thicker and of larger cells on the wall than on the free side of ascending branches which is assumed to have become inherited dorsiventrality.

Kny's study of the roots of both hyponastic and epinastic species showed that no regularity occurs in the excentricity of radial growth and it was thought that local pressure relations may determine the excentricity in roots. The lateral roots were cut from small seedlings of Tilia, Picea and Gleditschia and, after they had begun to develop new roots, they were placed in darkened Knop's solution and allowed to grow. No excentricity resulted except in some cases where the upper radius was greater at the origin of the root from the axis. An examination of horizontal roots which had been exposed for years, showed that their excentricity is the same as that of the branches of the same tree. In a more recent paper he[39] came to practically the same conclusions and maintained that the same factors which induce excentric growth in aërial structures are in the main responsible for their occurrence in roots. The atmospheric environment was thought somehow to be the causal agent.

A new and rather striking application of the bark-pressure hypothesis of Sachs and de Vries was made by Detlefsen[40] in explaining excentric radial growth. He pointed out the obvious fact that on the concave side of a curved stem radial growth must necessarily decrease while on the convex side it increases bark pressure chiefly because of the effect such growth has upon longitudinal tension of the bark. Owing to the presence of the hard-bast fibers in the bark the reduction of the pressure on the cambium becomes effective some distance on both sides of the curve. The bark was usually found to be considerably thicker on the side of a stem having the greater radius and it was frequently wrinkled or at least more rugged. He held, therefore, that the excessive thickening in the upper angles of large lateral roots and in the lower angle of branches is due to the reduced bark pressure at those places following radial growth, and that the ridges extending from such roots up the trunks are secondary

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[39] Kny, L. Über das Dickenwachstum des Holzkőrpers der Wurzeln in seiner Beziehung zur Lothlinie. Ber. Deut. Bot. Ges. 26:19–50. 1907.

[40] Detlefsen, E. Versuche einer mechanischen Erklärung des excentrischen Dickenwachsthums verholzter Aschen und Wurzeln. Arbeit. Bot. Inst. Würzburg. 2:670–88. 1882.

effects of the same thing. In case of branches, it was assumed that their weight increases the longitudinal bark tension above and reduces it underneath. Trees having one-sided tops were said to also be affected by the increase of bark tension on the side with fewer branches and a decrease on the top-heavy side, thus resulting in excentric growth of the stem with the greater radius on the side having more branches. A case was described in which a large horizontal branch had a sharp lateral bend on the concave side, which had resulted in a marked increase in radial growth with only a slight increase on the lower side. On such an assumption as this of Detlefsen it is conceivable that, after the excentricity in the upper angles of lateral roots has once become marked and a tree has attained some age, it may become more and more pronounced until a buttress-like structure results. However, he failed to mention epinastic branches.

Kny[41] has also noted that bending roots of herbaceous plants and allowing them to grow in the bent position results in excessive growth of both xylem and cortex on the concave side.

According to Mer[42] the two chief causes for excentric radial growth are those affecting the manufacture of organic food and those influencing cambial activity. The factors affecting the former are the slope of the land, proximity to other trees, fertility of the soil, exposure, etc., while those influencing cambial activity are thought to be mechanical strains due to wind, gravity, traumatism, etc. Sloping ground is said to induce an increased growth on the hill and a reduced growth on the valley side. Trunks were more commonly found excentric in thick than in thin forest stands and the excentricity was confined chiefly to the lower parts. When affected by the proximity of another tree the radius toward the influencing tree was shorter. Curvature was held to be the most frequent cause of excentric growth. Wounds were found to induce an excessive radial growth on the opposite side of the stem; and excentricity was found to be conducive to the occurrence of frost clefts.

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[41] Kny, L. Ueber den Einfluss von Zug und Druck auf die Richtung der Scheidewände in sich theilenden Pflanzenzellen. Jahrb. Wiss. Bot. 37:55–98. 1902.

[42] Mer, E. Recherches sur les causes d' excentricité de la moélle dans le sapins. Rev. Eaux et Forêts. Ser. 2:461–71; 523–30; 562–72. 1888. ——3:19–27; 67–71; 119–30; 151–63; 197–217. 1889.

Cieslar[43] performed an experiment which suggests the above cited observations by Nördlinger in that he bent over the tops of four eight-year-old spruce trees and tied them in a horizontal position in early summer, one was bent toward each of the four cardinal points. All ascending branches were also fastened horizontally. The trees were cut during the second winter following the beginning of the experiment and the radial growth was found to have become greater on the upright basal portion of the stems on the side of the bent-over tops. The excentricity increased from near the ground up to a maximum beyond the middle point of the turn where the stem was horizontal. Starting in the outer ring some distance above the inception of excentric growth and extending even into the outer part of the third ring, the wood on the side having the longer radius had a reddish color, which also became darker upward in proportion to the increase in the radius. That is, the rings produced the year before the trees were bent were also affected by the bending. It is also shown that the spring-growth of the affected rings is not discolored in the lower part of the stained region.

Such ''red-wood'' as described above is very commonly present in the under half at the base of pine and spruce branches. The physical properties of ''red wood'' have been studied in some detail and its histological characteristics have also received some attention. Although it seems not to occur in stem structure devoid of excentric growth, excentricity is not always accompanied by ''red wood.'' The fact brought out in the above cited paper by Cieslar that the summer wood may be affected while the spring wood of the same ring is normal is especially noteworthy because it shows that the factors producing ''red-wood'' are not effective throughout the year.

Hartig[44] made an investigation of the occurrence and distribution of ''red-wood'' in spruce and found that it is always present on trees which have excentric trunks and are located in isolated places or in thin and interrupted forest stands. Since ''red-wood'' occurs in portions of trees which appear to be subject to the greatest strains, Hartig thinks it arises in response to the mechanical requirements of stems. He found that inclined

[43] Cieslar, A. Das Rothholz der Fichte. Centbl. Gesam. Forstwesen. 22:149–65. 1896.

[44] Hartig, R. Das Rothholz der Fichte. Forst. Naturw. Zeit. 5:96–109; 157–69. 1896.

tree-trunks had a greater radius on the side toward which they slant and also have "red-wood" present on the side with the longest radius. In one instance a tree on the west edge of a forest and therefore having most of its branches on the west side was found to have a longer radius as well as abundant "red-wood" on the east side. In another case trees along the western edge of a forest had the typical excessive growth and "red-wood" on the east side of the trunks up to the age of about 80 to 90 years, after which the new rings showed a lesser excentricity and a smaller amount of "red-wood." The change seemed to have resulted from the presence of a new planting on the west side which had attained some size by that time. Hartig concluded that the mechanical or swaying effects of wind not only causes excentric radial growth but also induces the formation of "red-wood" on the side of trunks subjected to longitudinal compression. An instance is also cited in which the leeward side of a tree-trunk is excessively thickened from the base up but which was devoid of "red-wood" near the ground although it was abundant farther up. A case is described where the distal part of a young spruce stem had been bent into a complete turn and had grown in that position during 27 years. Sections cut at various points of the curve showed the occurrence of the greatest radial growth and of "red-wood" on the sides where gravity and longitudinal compression resulting from the top-weight and wind action would require it. The excentricity of large spruce branches and the accompanying "red-wood" was found to extend only about four meters out from trunks.

According to Hartig "red-wood" has comparatively large intercellular spaces and the cells seem not to be very firmly attached since they frequently fell apart in sections. The tracheids are said to have especially thick walls the innermost thickening layers of which are arranged spirally.

In a more recent summary of his investigations of wood Hartig[45] claims to have proved the relative influence of gravity and longitudinal compression in inducing the formation of "red-wood." Spruce trees planted in large tubs were suspended in an inverted position in a greenhouse and the distal part of the stems were bent upward and allowed to grow during one sea-

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[45] Hartig, R. Holzuntersuchungen. Altes und Neues. Berlin. 1901. pp. 99.

son. The excessive growth at the curve and the accompanying "red-wood" was found to have developed on the under or *convex* side of the curve. This was assumed to indicate that gravity has more influence in the production of "red-wood" than longitudinal compression.

Rubner[46] has given us some interesting observations on excentrix as well as of more irregularly distributed radial growth of trees. He called attention to the fluted or furrowed trunks and buttressed trunk-bases so characteristic of certain species. He attributed the ridges to excessive and the valleys to subnormal radial growth. In Carpinus the deep, wide grooves in the stem were found to occur at places where several compound medullary rays are grouped together, while lesser depressions or channels occurred along each individual compound ray, but these lesser grooves were practically compensated for by the greater phloem production so that the outer surface of the bark did not show them. In portions of trunks represented by the ridges the rays were small and it was assumed by Rubner that the distribution of the large and small rays influences the relative amounts of radial growth of the ridges and valleys in the wood cylinder. While Nördlinger[47] assumed that the valleys are due to an excessive bark pressure along the large rays owing to the development of stone cells or abnormally long phloem-ray cells in the bark at such places. He notes the absence of marked valleys and grooves in oaks devoid of broad rays, and that on very large, old trees the outer rings often have the valleys between the large rays while the ridges occur along the rays. The armpit-like depressions below some branches, according to Rubner, occur under branches whose leaves elaborate only enough food for their own use thereby leaving the region just below the branch bases insufficiently supplied, owing to the deflection the branch-bases cause in the downward current of food in the trunk. These depressions are said to be chiefly confined to epinastic species. In the valleys Rubner found the wood to consist mainly of thick-walled fibers and the radial arrangement of the cells was perfect, apparently because the valley-wood is devoid of vessels. The large "false rays" present in the valleys of Carpinus

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[46] Rubner, K. Das Hungern des Cambiums und das Aussetzen der Jahrringe. Naturw. Zeit. Forst-u. Landw. 8:212–62 1910.

[47] Nördlinger, H. Wirkung des Rindendruckes auf die Form der Holzringe. Centralbl. Gesam. Forstwesen. 6:407–13. 1880.

were found to develop in the second and subsequent annual rings by the elimination of most of the wood cells between adjoining rays. Eames[48] has noted a similar compounding of the simple rays of white oaks. Rubner found that the ray cells in the valley wood are shorter than those in the ridge-wood. The wood in valleys often showed no indication of rings because the cells were frequently all of the summer-wood type with a reduced radial diameter. In the deep valleys many rings were found to converge into a homogeneous layer of small cells many of which had brownish contents. In some cases as many as twenty-two year's growth had occurred on the ridges while no growth resulted in the valleys. In some such instances the cambium in the valleys had become thick-walled and apparently lost its power of growth and in others it had died and turned brown. In the smaller valleys of trunks phloem production was found excessive while on the ridges it was only slight. Rubner also described instances in which no radial growth resulted on the lower portion of tree-trunks during a number of years. He found that long branches with sparse foliage have very irregularly distributed radial growth, often being wholly omitted in some portions and present in others, although at times with imperfectly differentiated cells. Similar irregularities were also noted by Ursprung[49] in branches of teak wood from the tropics; cross sections showed that in some growing seasons the cambium had been active in only a part of the circumference.

The work reviewed above shows that several types of excentric radial growth occur both in horizontal and upright structures and that some of them are apparently due to differences in bark pressure and to an excentric distribution of the transpiraiton current and metabolized food, while in others the cause of the excentricity is not shown. For instance these authors have not determined why radial growth should be distributed in scattered patches on branches or tree-trunks which have an inadequate supply of food or why fluted trunks and buttressed stumps should occur, although Detlefson made some interesting suggestions regarding the latter. Rubner has shown that radial growth is very slight in the valleys or grooves occurring in the

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[48] Eames, A. J. On the origin of the broad ray in Quercus. Bot. Gaz. 49:161–66. 1910.

[49] Ursprung, A. Zur Periodizität des Dickenwachstums in den Tropen. Bot. Zeit. 62: Abt. 1:189–210. 1904.

trunks of Carpinus, etc., and that the wood of these valleys contains the large aggregate rays while that in the ridges has simple ones. That the presence of the aggregate rays has induced the valleys by their early cessation of growth as Sorauer[50] held does not necessarily follow, though it may be true, as it is more recently implied by Bailey[51] and others. In a number of recent papers written by Jeffrey's students[52] it is maintained that the different types of rays and their method of development are of great phylogenetic significance in showing the paths of evolutionary development. Yet in the above cited paper by Bailey it is also noted that changed nutrition may markedly modify the rays and their distribution.

Some of Kny's[53] results obtained in his experiments seem to indicate that the pressure under which rays differentiate in the cambial zone has much to do in determining their size. He found on applying a pinch-cock to twigs of Salix and *Aesculus Hippocastanum* in spring that not only was radial growth almost entirely inhibited on the compressed sides but that the ray cells were broader in tangential direction and that in some cases a doubling of the typically simple rays had occurred in both trees. In the above cited paper on the causes of excentric growth Mer also calls attention to the increase of radial growth on trunks opposite a wound. This observation of Mer's is of interest here chiefly because the occurrence of traumatic rays[54] in wood pro-

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[50] Sorauer, P. Handbuch der Pflanzenkrankheiten. Zweite Auflage. 1:537. 1886.

[51] Bailey, I. W. The relation of the leaf-trace to the formation of compound rays in the lower Dicotyledons. Ann. Bot. 25:225–41. 1911.

[52] Bailey, I. W. Reversionary character of traumatic oak woods. Bot. Gaz. 50:374–80. 1910.

Eames, A. J. On the origin of the herbaceous type in the Angiosperms. Ann. Bot. 25:215–24. 1911.

Thompson, W. P. On the origin of the multiseriate ray of the Dicotyledons. Ann. Bot. 25:1005–14. 1911.

Holden, R. Reduction and reversion in the North American Salicales. Ann. Bot. 26:165–73. 1912.

Bailey, I. W. The evolutionary history of the foliar ray in the wood of the Dicotyledons, and its phylogenetic significance. Ann. Bot. 26:647–61. 1912.

[53] Kny, L. Ueber den Einfluss von Zug und Druck auf die Reichtung der Scheidewände in sichtheilenden Pflanzenzellen. Jahrb. Wiss. Bot. 37:55–98. 1902.

[54] Jeffrey, E. C. Traumatic ray-tracheids in Cunninghamia sinensis. Ann. Bot. 22:593–602. 1908.

Bailey, I. W. Reversionary characters of traumatic oak woods. Bot. Gaz. 50:374–80. 1910.

duced on the side of a stem opposite a wound is assumed to have phylogenetic significance.

According to Groom[55] the evolution of the rays in Quercus is not as simple as presented by Eames, Bailey, Thompson and others for he found cases where the primary rays seemed to branch like those of beech described by Jost[56] as well as others where the aggregations occurred in the manner described in the above cited papers. Groom is inclined to the view that ray development and architecture is based on physiological rather than on phylogenetic factors and that it is impossible at present to decide whether the narrow or the broad-rayed type is the more primitive.

It is also worth noting that, although Nördlinger[57] found the valleys originating along the groups of broad rays and that oaks without the broad rays are devoid of valleys, in case of very large old trees the ridges were often found to occur along the broad rays, while valleys were present between them, i. e. just the reverse of the conditions obtaining in younger specimens.

Perhaps it might prove worth while to find out whether the occurrence of valleys and ridges in such trees is due to differences between the rate of growth in the wood and in the rays rather than being due to an early cessation of ray growth as Sorauer had assumed. In case the formation and radial elongation of ray cells were very slow as compared to the radial increase in the wood cylinder in general, it is conceivable that the solid broad rays may have a dominating influence and retard radial growth on both sides of them because of the firm attachment between the rays and the surrounding tissues. If the claim made by Klebs[57] that the presence of large quantities of elaborated food retards radial growth should prove correct and since these large rays are the storage reservoirs for elaborated foods it would also be understandable how they might be comparatively slow growing in youth and comparatively more rapid in old age, when radial growth has become slow.

The conspicuous ridges on the lower part of trunks correspond

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[55] Groom, P. The evolution of the annual ring and medullary ray in Quercus. Ann. Bot. 25:983–1003. 1911.

[56] Jost, L. Ueber einige Eigenthümlichkeiten des Cambiums der Bäume. Bot. Zeit. 59:1–24. 1901.

[57] Nördlinger, H. Wirkung des Rindendruckes auf die Form der Holzringe. Centbl. Gesam. Forstwesen. 6:407–13. 1880.

[57] l. c.

with the occurrence of the upper lateral roots. In trees like the elms, ironwoods, and oaks the excessive thickening in the upper angle primary roots make with trunks are often exaggerated into buttress-like enlargements which are continued as ridge-like prolongations extending some distance up the trunks. According to Detlefsen[58] the excessive radial growth in the upper angle of lateral roots and in the lower angle which large branches make with the trunks is chiefly due to a continued decrease of the bark pressure at these places which results from radial growth. This hypothetical explanation, however, requires an experimental basis. The fact that the bark at these places is often cleft or ruptured rather shows that radial bark pressure, at least, occurs there. The pressure exerted against the bark by the growing wood is not only sufficient to bring about tension at the root and branch ridges but tension of sufficient magnitude to rupture the bark in many instances. The experiments by Vöchting[59] in which the distal tips were cut from Helianthus and other plants with the result that the stems became somewhat fleshy and in some cases rib-like thickenings developed over the leaf traces and ran some distance down the stem, can scarcely be said to apply owing to the fact that in Vöchting's experiments the excessive thickening was chiefly due to increase in the pith and cortical parenchyma instead of radial growth of the stele.

It has been suggested or inferred by some of the above as well as by other writers that greater cambial activity occurs in the upper angle of roots at their origin from the stump than takes place in the lower angle, because the downward current of metabolized food is checked and accumulates more or less in the upper angle. The lower angle of the root is said to be more indirectly and, therefore, more sparsely supplied with food and for that reason one sided radial growth results. An additional factor, which contributes to this excentricity, is doubtless the pressure of the tree's weight on the cambium of the underside and another may be the reduced longitudinal bark tension suggested by Detlefsen. Even in case of a tree with a deeply penetrating tap root a very marked radial increase on the lower side of large primary laterals would tend to elevate the entire tree, and a tree without a tap root must be carried chiefly by the large

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58 l. c.
59 l. c.

primary laterals and therefore exerts great pressure on the cambium as Detlefsen[60] maintained.

According to another group of investigators to be cited in the discussion on the distribution of radial growth, excentric growth is not due to an independent distribution of metabolized food and the other factors commonly assumed to be effective. Both food and growth are held to be distributed by the mechanical effects of the environment in conjunction with the weight effects of the structure in question or by the rate and path of the transpiration current.

THE GENERAL FORM OF TREE-TRUNKS AND THE DISTRIBUTION OF RADIAL GROWTH.

The distribution of radial growth on trees determines the form of the stem and therefore its value as timber. Owing to the economic importance of the shape of tree-trunks to the lumbering industry foresters studied the distribution of radial growth and its relation to the environment very extensively and have collected many valuable data. Since the stem of a tree grown in a fairly dense and uniform forest stand is relatively longer and less tapering toward its upper end, free of branches and therefore of more lumbering value than one grown in the open, the differences in the environment of the two types have received much attention.

Nördlinger[61] noted that the yearly increase in thickness on the branchless and branched parts of stems grown in a forest differed from each other. The annual distribution of radial growth on the branch-bearing portion in a forest stand was found to be similar to that on the entire trunk of a free-standing tree, which bears branches nearly to its base. The thickness of the wood rings in the branch-bearing part of stems was found to decrease from the base upward. On the branchless portion of trunks in dense forest stands the thickness of the recent rings was noticed to have decreased from the branches downward although in some cases the thickness of the new yearly growth remained practically constant at the base of trunks. He thought that the presence of elaborated food was not the only requisite for the occurrence

[60] l. c.
[61] l. c.

of radial growth in any particular region of a tree-trunk for the reason that the radial growth maxima in dense stands move upward more rapidly than would be demanded by the reduction in metabolized food.

Sanio[62] noted that in case of a dwarfed fourteen-year-old sapling of *Fraxinus excelsior* growing in a swamp the spring wood was for the most part very thin and usually had but a single row of vessels while in some parts of the stem the rings were devoid of vessels. He thought it likely that spring growth had been wholly omitted at such places and that the ring there contained only summer-growth wood.

R. Hartig[63] has probably published more on the general distribution of radial growth than any other investigator. From a study of overtopped pines and spruces between 20 to 30 years old, he found that the rings became thinner from the branched top downward and that in some cases as many as seven rings had been entirely omitted on the lower part of stems. When rings had been omitted during a series of years the lower edges of the new rings or wood-sheaths were found to have receded farther from the base each year. In another paper he[64] called attention to the fact that in overtopped trees a reduction occurs in the yearly amount of wood produced from the branches downward.

In general a stem is said to have three more or less distinct growth regions in each of which a typical distribution occurs.[65] In the main axis of the branched top the cross sectional area of the growth rings is said to increase from above downward. The rings on the branchless shaft also increased in thickness from the branches downward in trees having a well developed top, but as stated above, the reverse was found true of a dominated tree with a small top.

A more detailed study of the distribution of radial growth was carried out by Hämmerle[66] in connection with his observations

[66] Hämmerle, J. Zur Organization von Acer Pseudoplatanus. Biblio. Bot. 50:1–101. 1900.

[62] Sanio, K. Verleichende Untersuchungen über die Zusammensetzung des Holzkörpers. Bot. Zeit. 21:391–99. 1863.

[63] Hartig, R. Das Aussetzen der Jahresringe bei unterdrückten Stämmen. Zeit. Forst.-u. Jagdwesen. 1:471–76. 1869.

[64] Hartig, R. Zur Lehre vom Dickenwachsthum der Waldbäume. Bot. Zeit. 28:505–13; 521–29. 1870.

[65] Hartig, R. Ueber den Entwicklungsgang der Fichte im Geschlossenen Bestande nach höhe, Form und Inhalt. Forst. Naturwiss. Zeit. 1:169–85. 1892.

on the elongation growth of young maple trees. He found that the greatest thickness of each ring normally occurred in the hypocotyledonary or crown region of young trees. The second ring of the branches was thicker toward the end than in the middle but subsequent rings decreased regularly toward the distal end. The third ring of a rather dwarfed, overtopped specimen had its greatest thickness in the three-year-old branches and diminished toward the base until at the height to which the tree had grown by the end of its first year, the ring was almost invisible; at the hypocotyl or crown region and at least as far as 19 cm. downward on the roots no growth at all had occurred during the third year. The bark in all cases was thickest at the hypocotyl or crown region.

From the papers cited in this section as well as from others noted elsewhere it is very evident that the distribution of radial growth is at least quite strongly influenced if not entirely determined by the environment and it will be interesting to examine some of the papers in which the factors that have been advanced as being the regulators of this distribution are discussed.

The publication of Schwendener's[67] epoch-making paper on the mechanical principles underlying the structure of Monocotyledons gave a view of plant anatomy from a new angle and still exerts a marked influence on both physiology and anatomy. Many measurements and calculations obtained from typical Monocotyledons are presented in this paper in support of the hypothesis that plant structures take on forms and have the supporting tissues distributed in them in such a fashion as to meet the mechanical requirement necessary to make such structures most efficient in carrying their own weight as well as in resisting injurious bending by the wind, etc. In replying to some severe criticism of this paper he[68] admitted that many inaccuracies occur in the calculations but maintained that on the whole it is correct. The general principle developed in the first paper is here also reinforced in its application to Dicotyledons but in a less thoroughgoing way. It was noted that radial growth in a tree-trunk seems to be distributed in a manner so as to meet the

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[67] **Schwendener, S. Das mechanische Princip im anatomischen Bau der Monocotylen mit vergleichenden Ausblicken auf die übrigen Pflanzenklassen. pp. 179. 1874.**

[68] **Schwendener, S. Zur Lehre von der Festigkeit der Gewächse. Sitzungsber. K. Preuss. Akad. Wiss. Berlin. 1884:1045–70. 1884.**

mechanical needs in supporting the top in its environment. The general form of trunks was found to conform more or less completely with shafts constructed to be of equal endurance throughout and capable of supporting a given load (top) and wind-pressure. It is said that owing to this fact a tree trunk grown in the open and therefore bearing branches nearly to the ground is thicker at the base than one grown in a forest and crowded by other trees.

Some years later Metzger[69] published some results and observations from which the striking conclusion is drawn that light, warmth, moisture and food *enable* a tree to grow but that the wind determines *how* it shall grow. He points out the self-evident but none the less interesting fact that a tree-trunk must not only carry its own weight and that of the branched top but also resist the wind action as it shifts the center of gravity while swaying to and fro. The tree stems are said to be the pillars of the forest and in order that the forest exist they must be both rigid and at the same time elastic enough to withstand strong winds. This is illustrated by him by imagining a wooden shaft firmly fixed in a horizontal position at one end and weighted at the other, thus resulting in the greatest strain at the place of attachment. If such a shaft is to be equally liable to break at any point of its entire length its cross sectional area must decrease from the point of support to the application of the weight or force in accordance with the physical laws involved, and the most economical use of the material of the shaft would require such a construction. By making numerous measurements and calculations it was found that the proportional thickness and form of tree-trunks below the branch-bearing tops was practically that required of the shaft described above, except that most of them are enlarged at the base or root-crown beyond the hypothetical requirements. It is noted that tap-rooted trees in deep soil are devoid of the excessive basal enlargement, and it is therefore thought that the enlargement is only a result of developing an adequate root anchorage for the tree. That portion of the stem in the branching top was also found to conform to such a shaft.

In case of horizontal branches it is held that their own weight overbalances wind action as a formative factor, while in upright

[69] Metzger, A. Der Wind als massgebender Faktor für das Wachsthum der Bäume. Mündener Forst. Hefts. 3:35–86. 1893.

branches like in trunks wind effects predominate over the weight of the structures themselves as formative stimuli. Branches in positions intermediate between these two extremes are said to be correspondingly influenced by the two factors. Since conifers of various sizes were found to conform very closely to the hypothetical requirements, Metzger thought it logical to assume that wind and the weight of the supported structures themselves are the factors instrumental in shaping tree-trunks or distributing radial growth on them. When the lower branches of a free-standing tree were removed, it was found that the annual growths on the lower portion of the trunk were reduced in cross-sectional area in very nearly the proportion required by the hypothetical considerations of the upward movement of the point of greatest stress. When a free-standing tree is encompassed by young trees radial growth of its trunk decreases from above downward as required by this hypothesis. When forest trees are left free-standing by the removal of surrounding trees radial growth is found to increase on their trunks from above downward and to decrease below normal on the upper part of the stems. In conformity also with the above hypothetical requirements the tall or over-topping trees in a forest of mixed sizes undergo most radial growth on the lower parts of the trunks while the overtopped trees grow more on the upper part of trunks.

Although these conclusions were based on data, which were obtained from spruce, Metzger[70] thinks them applicable to the distribution of radial growth of trees in general. According to him the wind, acting as a stimulus through its mechanical effects upon trees, also regulates in a general way, the distribution of the elaborated food as well as that of radial and elongation growth in accordance with the relation of the form of the top, etc. to wind-exposure. It is said that during the first and second year after the thinning of a forest most of the available food is used up in increasing radial growth on the lower part of the trunks so as to increase the wind resisting power of the suddenly exposed trees, but afterwards elongation growth proceeds rapidly. In some cases of this kind it is held that the top may be

[70] Metzger, A. Studien über den Aufbau der Waldbäume und Bestände nach statischen Gesetzen. Mündener Forstl. Hefte. 5:61–74. 1894. Mündener Forstl. Hefte. 6:94–119. 1894.

deprived of marked radial as well as elongation growth for several years, and the long-continued scarcity of food in the upper part of the top is said often to result in the dying back of the upper branches and thus gives rise to stag-horn effects. The length of time required for adjustment to the new environment is said to depend upon the extent of a tree's leaf surface. The sprouts, which often arise on long bare trunks, are thought to be induced by the swaying action of the wind thus tending to develop a lower head.

An enormous amount of data and calculations on the relation of the environment to radial growth and its distribution was also callected by Schwarz[71] and published as a monograph which in addition contains many very important observations on the life and seasonal history of *Pinus silvestris*. It is noted that yearly radial growth as measured by the area of its cross section increases in trees until the age of about 20 to 30 years is reached, but under very favorable environmental conditions its growth may increase to the age of 100 years. His general conclusions regarding the wind in its relation to the distribution of radial growth are practically the same as those put forth by Schwendener and Metzger. Some instances are cited where the tops of trees had been broken off when about 30 years old and which had since grown about 60 years with lateral branches diverted to function as the main axis. In the region of curvature of the branch which assumed the functions of the main axis excentricity became very marked, with the greater radius on the under side. It is thought that the excessive pressure or weight on the under side was the stimulus to increased radial growth on that side. In one case, in which the curvature induced had been such as to exert the greater pressure on the upper side in one place, it was found that this upper side had the greater radius. Many measurements on vertical stems also showed a greater radius on the leeward side in regard to the prevailing wind. By tying a young pine tree in a bent position excessive growth resulted on the compressed side, i. e. it seems that a fixed, bent position exerts the same influences on radial growth as the discontinuous pressure due to wind swaying. Other measurements on slightly inclined trees also showed a greater radius on the side toward which the trees inclined. It is held that relative amounts of

[71] l. c.

elaborated foods present in different regions of trunks is not primarily responsible for the distribution of radial growth, for on such an assumption the greatest growth would always occur on the stem just below the branches, while as a matter of fact it usually occurs within two meters of the ground. In fact it is claimed that both the distribution of metabolized food and radial growth are regulated by the wind-pressure-and-weight stimuli. The wind effects are thought to induce the transfer of most of the food elaborated in the leaves of a recently isolated tree to the lower part of the trunk where increased radial growth is caused by the increase of the mechanical wind-stimulation. Attention is called to the fact that in case of excentric annual rings the excentricity is chiefly due to an excessive production of the so-called summer wood, thus upholding the view that swaying and weight stimuli are especially effective during the latter part of the period of radial growth. The data seemed also to show that after trees with excentric rings are perhaps about 73 years old or have begun to decline in their rate of growth the new rings decrease markedly in excentricity and in conformity with that it is noted that late season growth is less in trees which have reached the age of decline in growth rate.

Schweinfurth[72] reported that about the Red Sea tree trunks all have a greater radius on the south side owing to the occurrence there of a continued and strong north wind during the summer. The presence of reduced branches on the north side is thought to have caused the reduced growth on that side.

A more detailed application to Schwendener's mechanical principles of plant structure to excentric radial growth in branches was made by Ursprung.[73] He maintained that the distribution of radial growth of both stem and branches is determined by the compression-strain stimulus resulting from the weight of the structure and the action of the wind. Non-vertical stems and branches were usually found to have an elliptical cross section with the longer diameter in the direction of gravity. This is said to increase the carrying capacity of the wood because the force required to bend such a branch in a vertical plane is proportional to the third power of the vertical diameter and to

[72] Schweinfurth. Sitzungsber. Ges. Naturfor. Freunde. Berlin 1867. p. 4.

[73] Ursprung, A. Beitrag zur Erklärung des excentrischen Dickenwachstum. Ber. Deut. Bot. Ges. 19:313–26. 1901.

only the first power of its horizontal diameter. He also concluded that vertical stems may become excentric owing to one-sided action of wind but that the effect on some trees might be different on account of variations in the shape and the consequent distribution of the weight of the top. The crooks in a tree trunk are assumed also to be gradually eliminated by the distribution of the radial growth in response to strain stimuli. The same laws are thought to apply to the radial growth in roots but because of the variation in the environing soil they are not always so regularly effective.

Vöchting[74] cut the tips from some potted one-year-old savoy plants and placed them with their pots in a horizontal position. He attached weights to some near their decapitated tips and allowed them to vegetate during some months. The vertical diameter of the stems was markedly increased in the regions of greatest strain while the stems of the check plants retained their cylindrical forms.

The far-reaching applicability of this wind-gravity hpyothesis originating with Schwendener and elaborated by Metzger and others, according to which tree-trunks and other stem structures have a form required of a shaft of equal endurance throughout, has recently been questioned by Jaccard.[75] He holds that the hypothesis is untenable because measurements and calculations made by him on a number of spruce trees resulted in a nonconformity of the hypothetical and actual forms of their trunks. It was found that the portions of the trunks beginning with 5 m. above ground and extending to about 9 m. above ground were practically of the form and dimensions required of such a shaft but above and below that region the trunks were thicker than required by the laws of mechanics. In one instance described in detail, however, the trunk of a spruce practically conformed to the required hypothetical shaft.

Although much more frequent strong winds are said to occur in western Switzerland the trees there were not found to differ appreciably from those of eastern Switzerland where strong winds are few. Jaccard maintained that during the growing season the wind is too spasmodic to be a factor in the distribution

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[75] Jaccard, P. Eine neue Auffassung über die Ursachen des Dickenwachstums. Naturw. Zeit. Forst-u. Landwirts. 11:241–79. 1913.

of radial growth, and besides, he holds that the distribution of growth on a tree-trunk having concentric rings could not conceivably be dependent upon wind action. From the measurements and calculations it is concluded, however, that tree-trunks are shafts of equal water conductance throughout. From insufficient data and non-convincing arguments it is concluded tion mentioned above, though larger than necessary for the wind-that the diameter of tree trunks above and below the 5 to 9 m. portion mentioned above, though larger than necessary for the wind-gravity hypothesis are of just the size required of a shaft of equal water conductance throughout. The morphogenic power of the water current is thought to be proportional to the rate of metabolism and transpiration. The rate of cambial division is held to depend upon and be controlled by turgidity, and the influence of the environment is thought to affect radial growth chiefly through the transpiration stream. In the calculation upon which this hypothesis is founded it was assumed that the water conduction is confined to the outermost ring or wood sheath.

This hypothesis has some defects in common with the one it is supposed to supplant in that the distribution of radial growth is assumed to be controlled chiefly by one factor, other factors being effective only in so far as the basic one is influenced. Jaccard has many difficult problems to solve before his hypothesis to account for the actual distribution of radial growth in trees can be considered a theory. The relation of the first radial growth and its distribution in trees to the transpiration stream in cases where such growth precedes actual unfolding of the leaves will need to be explained in the promised detailed study he is to publish in a future paper. Nor is it permissible to assume as a fact that the water current is confined to the outermost ring of wood, especially when it is recalled that in certain portions of trunks radial growth may be wholly omitted during a number of successive years, and that many cases of girdling are also on record in which trees operated on vegetated and fruited normally during several years.

Wieler[76] concluded that practically all water is conducted in

[76] Wieler, A. Ueber den Antheil des secundären Holzes der dicotyledonen Gewächse an der Saftleitung und über die Bedeutung der Anastomosen für die Wasser-versorgung der transpirirenden Flächen. Jahrb. Wiss. Bot. 19: 82–137. 1888.

the last ring but in a more recent study Jahn[77] made it appear that the entire alburnum may be more or less active in water conduction although perhaps as much as half or more of the water is thought to be carried up the last ring.

Some evidence of the fact that wind is both a formative and a limiting factor in plant growth is afforded by several scattered papers on the influence of wind on vegetation, a few of which might be briefly noted in this connection.

While making an experimental study of the effects of wind on vegetation Bernbeck[78] obtained some interesting results. He found that both shoots and leaves of plants subjected to wind of 14 m. or less per second were injured in proportion to the amount of swaying and bending induced and that even delicate leaves of shade plants are not injured by the wind if they are firmly held to prevent swaying or bending during the exposure. It was found that the production of organic food was reduced in leaves exposed to wind as compared to that accumulating in protected leaves.

Gilchrist[79] reported that potted plants of *Helianthus annuus* subjected to artificial wind swaying and rocking did not grow as tall as the checks while the diameter of their stems exceeded that of the check plants. Some more recent observations by Cavara[80] show a similar effect of wind exposure on the structure of Iresine, Coleus, Aster, Zinnia, and Sempervivum.

Esbjerg[81] found that protecting various herbaceous plants from strong winds by means of screens resulted in an increased yield. An increase of 16 to 31% above that of the checks was secured in the yield of grain from rye; the yield of ruta-baga roots was increased from 7 to 17% and of mangels from 3 to 18%, while clovers and grasses showed a gain of from 4 to 23% as a result of wind protection.

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[77] Jahn, E. Holz und Mark an den Grenzen der Jahrestriebe. Bot. Centbl. 59:257–67; 321–29; 356–62. 1894.

[78] Bernbeck, O. Der Wind als pflanzen-pathologischer Faktor. Inaugural Dissert. Bonn. 1907. pp. 116.

[79] Gilchrist, M. Effect of swaying by the wind on the formation of mechanical tissue. Report Mich. Acad. Sc. 10:45. 1908.

[80] Cavara, F. Some investigations on the action of wind on plant growth. Expt. Sta. Record. 25:224–25. 1912.

[81] Esbjerg, N. Experiments with windbreaks. Expt. Sta. Record 23:435. 1910.

Similar facts are also reported by Waldron[82] from North Dakota. While from Porto Rico[83] we learn that the northeast wind prevailing there causes citrus trees to grow slowly and one-sided in unprotected places; the bark looks dead and the new shoots are variously twisted. A case is cited where two similarly planted citrus groves are located across the road from each other but one is protected by a windbreak while the other is fully exposed. The trees had all been set three years and were bearing in the protected grove while in the exposed one they looked as though they "had just been set." Wind-exposed trees were also found heavily infested by scale-insects while the protected ones were practically free from the pest.

In a very recent paper[84] it is stated that the wind induces dwarfing and the rosette habit, although the structural modifications are attributed to excessive transpiration.

A like conclusion was recently also drawn by Choux.[85] He found that the stems of *Neptunia prostrata* and of *Ipomea reptans* grown during the tropical dry season were not only smaller but that their vascular systems were much more strongly developed than in those produced during the wet season. Starch was abundant in the dry season plants and practically absent from those grown in the wet season.

The hypothesis advanced by Schwendener and subsequently elaborated by Metzger and Schwarz and the more recent one by Jaccard are so simple and imbued with such insidious directness that they are fascinating although not wholly convincing. After making a brief survey of the observations and experiments by Jost, Lutz, Fabricius, Rubner, etc., it seems as though the occurrence and distribution of radial growth could not be dependent on a single factor. It appears for instance that the distribution of elaborated food must in part at least depend upon its place of manufacture and on the channels of its transport, especially when the amount available is somewhat below the

[82] Waldron, C. B. Windbreaks and hedges. N. Dk. Agrl. Expt. Sta. Bul. 88. 1910. pp. 11.

[83] Tower, W. V. Insects injurious to citrus fruits and methods for combating them. Porto Rico Agrl. Expt. Sta. Bul. 10:16–20; 35. 1911.

[84] Kroll, G. H. Wind und Pflanzenwelt. Beihefte Bot. Centralbl. 30 Abt. 1:122–40. 1913.

[85] Choux, P. De l'influence de l'humidité et de la sécheresse sur la structure anatomique de deux plantes tropicales. Rev. Gen. Bot. 25: 153–72. 1913.

actual needs. On the other hand from the work of both Jost and Lutz it is also evident that the presence of food, transpiration current and suitable environment alone do not result in radial growth when no developing buds or shoots are present; i. e., cambial activity seems somehow to be dependent upon elongation growth or some enzyme activated or produced by it. The determinations by Fabricius, however, have made it apparent that the distribution of reserve food in tree-trunks seems to be in accordance with some unknown law, which brings about maxima and minima of food storage in more or less definitely alternating regions. The marked differences in the amounts of reserve food in the regions of maxima and minima could not be attributed to differences in the storage capacity of the regions for such differences would have been noted, nor to the distribution of the branches because the wave-like succession of maxima and minima also occurred and it was usually most marked on the branchless portion of trunks. There is some indirect evidence to be had from the cited papers which tends to show that the places of the inception and longest duration of radial growth in a general way are the places of maximum food storage, and therefore gives support to Mer's[86] contention to the effect that radial growth begins first where most food is stored and is most active and persists longest in such regions. The Schwendener–Metzger–Schwarz hypothesis suggests another way out of the difficulty by its assumption that wind action is responsible for the distribution of both metabolized food and radial growth. But we cannot admit the far-reaching claim of these investigators that wind and gravity are the only formative factors concerned in the distribution of radial growth especially since light and transpiration have been shown to be powerful formative agents.

OBSERVATIONS ON THE DISTRIBUTION OF LATE RADIAL GROWTH ON FRUIT TREES.

While studying crown-rot of fruit trees during a series of years, I found that the initial bark injuries which afterwards result in the disease usually occurred in places at the base of

[86] Mer, E. Sur les causes de variation de la densite' des bois. Bul. Soc. Bot. France. 39: 95–105. 1892.

tree trunks where radial growth continues late in fall. The observations made to determine the distribution of late radial growth showed that it is very irregularly distributed, yet that when it occurs it is confined to certain parts of trees. Cranefield[87] has called attention to the general variation of radial growth in branches. After two seasons observations he concluded "that a wide difference existed between trees of the same variety, age and external appearance, and that the difference was often greater between different branches of one tree than between different trees." In 1899 he found that the bark peeled readily on all branches of apple, pear, plum and cherry as late as August 15, and after that date the bark still peeled easily for some time on the larger branches. In 1900 the bark of branches over 1 cm. in diameter slipped easily enough to make whistles as late as September 15, while two weeks later it would not peel from any of the branches.

Although observations like these of Cranefield show that marked variations may occur in the distribution of the last radial growth, it is apparent that its actual variation can only be determined by much more detailed examinations at numerous points not only of any one tree but of any one branch. Some of the above cited observations on the general distribution of radial growth and more especially those on excentric growth also suggest the inference that late growth is often very irregularly distributed and that it is perhaps frequently confined to regions of trunks and branches where excentric growth occurs. In a general way that represents the distribution of the late growth occurring in fruit trees.

Radial growth in apple and other fruit trees was most commonly found to continue latest in fall around the base of the trunk and its upper roots as well as about the bases of branches and around crotches; but in some cases other regions also underwent late growth. The distribution of late growth about the base of the trunk is apparently subject to many variations depending upon the place of origin of the large upper roots as well as on the size of the top. Usually the last growth occurs on the ridges of the roots approximately in the center of the rounded angle a root makes with the trunk, although in some

[87] Cranefield, F. Duration of the growth period in fruit trees. Wisc. Agrl. Expt. Sta. Ann. Rpt. 17:300–8. 1900.

cases it was found to occur equally late in the upward extension of such a root-ridge on the trunk. Again, in some instances in which trees had only two large lateral roots making a rather narrow angle with each other, very late growth was found to occur in the valley-like angle between them. From an earlier paper[88] on crown-rot and the papers cited there it is interesting to notice that the distribution of that disease on fruit trees conforms fairly closely to the distribution of late radial-growth occurring at the root-crown region. It was found that in cases where only a part of the bark was affected it was confined to the upper angles of lateral roots, or to the very deep angles between two large laterals.

Pruning fruit trees very heavily often results in a decided reduction in the thickness of the next annual ring toward the base of the trunk. This was found by pruning some fruit trees in one of the seedling apple orchards of the New York State Agricultural Experiment Station in early spring of 1912. The radial growth on the lower part of such heavily pruned trees also continued several weeks later than it did on nearby checks.*

The result seems to agree with those obtained by Jost, Lutz, and Kühns[89] in that a reduction of the foliage beyond a certain amount resulted in greatly reducing growth toward the base of the stem.

As stated above observations made regarding the occurrence of crown-rot on fruit trees seemed also to show a possible relation of that disease to the distribution of late growth. Some New York apple orchards may be used to illustrate this relation. In one instance[90] two varieties almost equally susceptible to crown-rot were grown side by side and received the same treatment except that the Baldwin variety was pruned up high while the other or Ben Davis variety was allowed to grow largely unpruned and therefore low headed. The Ben Davis trees had been set for fillers and were not deemed worth the care bestowed on the

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[88] Crown-rot, arsenical poisoning and winter-injury. N. Y. State Agrl. Expt. Sta. Tech. Bul. 12:389–94. 1909.

* The writer wishes to thank G. H .Howe of that station for having the pruning done, and R. Wellington, now of the Minnesota Experiment Station, for making some of the collections of specimens from these trees into killing fluids.

[89] l. c.

[90] Crown-rot of fruit trees: field studies. N. Y. State Agrl. Expt. Sta. Tech. Bul. 23:18–20, 46, and plate 7. 1912.

other variety since they were to be removed after the Baldwins had attained some size. Nearly all of the Baldwin trees had the bark injured about a decimeter above ground during the winter of 1910–11, and over 80% had practically entire girdles of loosened or injured bark so that they had become worthless, while none of the low headed Ben Davis trees were affected. In another case[91] bark injury resulted high up the trunks of bearing trees after a severe pruning.

It was also found that radial growth is often very late in thick callus rolls about old cankers and sometimes on the under side, or on the concave side of crooks in horizontal branches. The bases of water sprouts or adventitious ascending shoots that arise on the larger branches of excessively pruned young apple trees also undergo very late radial growth and apparently for that reason are winter-injured in those regions; as in some cases discussed on pages 40 to 42 of the above cited paper on crown-rot. Very similar observations regarding the distribution of winter-injury in the bark of trees had been made by Nördlinger.[92] He also assumed that such places are injured because of their late growth.

The reasons for the occurrence of late radial growth at certain places on trees are doubtless the same as those underlying the general distribution of excentric growth, and have not been fully determined as yet. It seems, however, that the re-distribution of bark pressure incident to radial growth, the distribution of elaborated food, the location of the channels for water conduction, and the gravity-wind pressure effects advocated as factors which regulate the distribution of radial growth, may afford at least a partial explanation of the localization of late growth after they have been submitted to a more careful quantitative study.

WHAT CAUSES RADIAL GROWTH TO APPEAR AS "ANNUAL" RINGS.

The general distribution of radial growth in trees has also an indirect relation to the development of "annual" rings in that the proportion of spring and summer wood of a ring at any level of a stem is doubtless dependent upon the comparative distribu-

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[91] l. c. p. 24–27.

[92] Nördlinger, H. Die September-Fröste 1877 und der Astwurzelschaden (Astwurzelkrebs) an Bäumen. Centbl. Gesam. Forstw. 4:489–90. 1878.

tion and duration of growth, in the early and late season, over the different parts of a tree. That is, if in any particular region of a trunk radial growth starts very early in spring and continues rapidly to the end of the spring-growth period a considerable layer of spring wood will occur in that region; while if spring growth starts late, proceeds slowly and stops rather early the thickness of spring wood would be slight. If the distribution of summer growth is such as to add but little to a region where spring growth had been heavy and much where spring growth had been slight, the rings resulting in the two regions would have a very different appearance. To continue the illustration further, if for some reason radial growth failed to occur in certain parts of a tree-trunk until after the production of summer wood had begun such parts would show only small-lumened, thick-walled cells in the ring; while had the summer growth been eliminated in regions where spring growth occurred the resulting ring would consist of spring wood only. From the papers cited above on the distribution of radial growth it is evident that all the cases illustrated here do actually occur even in the extreme forms used in the last illustration. It is apparent, therefore, that in some environments and especially on certain parts of trees the distribution of radial growth may have a marked influence not only on the type of the resulting ring but even on the nature of the wood in such portions of stems. This evident relation between the seasonal distribution of radial growth on a tree to the type of wood ring to be produced has reseived practically no attention, although in von Mohl's[93] paper on the anatomy of roots it is noted that rings with only the spring type of wood seem to result owing to the entire omission of the summer growth; while Sanio[94] suggested a similar idea regarding the absence of spring growth in parts of some rings of a dwarfed Fraxinus grown in a swamp. Lutz[95] also noted the absence of summer wood in a pine, from which the buds had been removed in March, the little growth that occurred was spring wood. When the wood of roots or stems grown in certain environments consist largely of so-called spring wood, elaborate explanations are usually manufactured to show that the high

[93] l. c.
[94] l. c.
[95] l. c.

water requirements of such habitats induce the formation of large vessels throughout the wood for the conduction of the water needed. This may be typically illustrated by a paper of von Lazniewski[95*] on alpine plans in which attention is called to the fact that the rings in mountain willows are much thinner and have a greater proportion of vessels per ring than those in trees of the same species grown in the valleys. Yet it was noted that the outer parts of the wood rings were usually only partially lignified, indicating that radial growth had been prematurely checked. The excessive number of vessels per ring of the alpine trees was interpreted as being due to the greater demands for water on the mountains, while the probable fact that the summer-wood portion of the rings had perhaps been wholly eliminated by the environment was not even mentioned. Practically the same observations although on a larger scale were made by Rosenthal[96] in a later paper and the conclusion was drawn that the larger number of vessels per unit area of cross section in willows grown on the mountains is an adaptation to a higher transpiration rate.

A number of hypotheses have been elaborated in an endeavor to explain "annual" rings, and more or less data has been collected by their supporters to substantiate them but with indifferent success as judged by Krabbe[97], who some years after publishing his last researches on the subject, maintained that ring formation cannot be satisfactorily explained with our present knowledge of the factors determining the size differentiating cells attain in different parts of the growing season, and of the ones regulating the thickness of cell walls in different parts of the rings.

It was recently pointed out by Klebs[98] that periodicity in plant growth occurs in all regions of the world having a periodic climate, and that the dormant periods coincide with the cold periods of temperate climates and with the dry periods of the tropics. He noted too, that some trees have partial and irregu-

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95* Lazniewski, von, W. Beiträge zur Biologie der Alpenpflanzen. Flora, 82:224–67. 1896.

96 Rosenthal, M. Ueber die Aushildung der Jahresringe an der Grenze des Baumwuchses in den Alpen. Inaug. Dissertation. Berlin. pp. 24. 1904.

97 Krabbe, G. Einige Anmerkungen zu den neusten Erklärungsversuchen der Jahringbildung. Ber. Deut. Bot. Ges. 5:222–32. 1887.

98 l. c.

lar periodicity even in regions of the tropics having what appears to be a practically non-periodic climate.

In central Uruguay[99] where the temperature never goes much below freezing and where late summer is a dry season, some trees have distinct yearly wood-rings, while in others more than one ring is produced in a year. *Robinia Pseudacacia* and *Melia azedarach* have fairly evident annual zones, but they also have imperfect secondary zones due to a concentric arrangement of large vessels. In Acacia the yearly zonation is less distinct but the last wood is usually made up of cells with a reduced radial diameter.

The measurements by Hall[100] show that the trunks of trees in Uruguay usually increase in circumference during nearly ten months of the year, and that in some cases they even increased during the months of May and June (winter). He found, however, that the circumference of most trees decreased more or less during winter, the deciduous trees more noticeably than the evergreens. Ursprung[101] found that a number of the evergreen trees and shrubs of a tropical locality without any appreciable periodicity of climate showed a zonation in cross sections of the stems without the presence of any evident histological difference in the wood of the different parts of zones. Some of these species are said to become deciduous in localities having a periodicity in the water supply with the result that the zonation of their wood becomes more marked. Holtermann[102] also studied the relation of climate to radial growth in the tropics and came to the conclusion that the formation of growth rings in the wood is intimately connected with the occurrence of periods of markedly different transpiration rates, and that the larger vessels are developed to meet the demands of increased transpiration. He holds that tropical trees growing in a saturated atmosphere most of the time have no indication of zonation in the wood even though they

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[99] Christison, D. On the difficulty of ascertaining the age of certain species of trees in Uruguay, from the number of rings. Trans. Bot. Soc. Edinburgh. 18:447–55. 1891.

[100] Hall, C. E. Notes on the measurements, made monthly at San Jorge, Uruguay, from January 12, 1885, to January 12, 1890. Trans. Bot. Soc. Edinburgh. 18:456–68. 1891.

[101] l. c.

[102] Holtermann, C. Der Einfluss des Klimas auf den Bau der Pflanzengewäche. Anatomisch Physiologische Untersuchungen in den Tropen. pp. 249. 1907. Leipzig.

are deciduous like some species of Leguminosae, Guttifereae and Ficus. On the other hand it is noted that a seven-year-old tree of *Theobroma Cacao* had developed 22 radial-growth rings, and since it cast its leaves three times a year it is evident that the number of rings corresponded with the vegetative seasons of the tree. The real cause of zonation is thought to be an inherent characteristic of a plant though the environment induces its manifestation.

According to Dingler[103] leaf-fall is more dependent on the age of the leaves than on the environment, for by cutting back deciduous trees in Ceylon some time before the normal period of leaf-fall the new crop of leaves which immediately came out was retained throughout the dormant season which is dry and very hot. Unfortunately the effect upon radial growth was not noted but from evidence given above it seems very likely that the periodicity of radial growth always follows foliar periodicity in deciduous trees whether natural or induced.

In another paper he[104] reported that the folier periodicity of European fruit and forest trees grown in the highlands of Ceylon is very irregular even in different branches of individual trees. In late October the trees of *Quercus pedunculata* could be divided into five classes in regard to the condition of their foliage, ranging all the way from cases in which chiefly old spotted leaves were present (though some scattered buds were swelling) to instances where no old leaves were present and the new shoots occurred in all stages of elongation, although most of them were full grown. *Quercus Cerris* had a more uniform periodicity. In late October all trees bore two generations of leaves: the old ones hard and spotted, althought still green, and the young ones not yet full grown. In late November the old leaves had practically all fallen and the new elongation growth had been completed. European pears, peaches, cherries, plums and apples were found to have practically the same periodicity, producing two crops of leaves and flowers, though but one crop of fruit per year. The trees are often almost leafless some time

[103] Dingler, H. Versuche über die Periodizität einiger Holzgewächse in den Tropen. Sitzungsber. Math.-Physical. Kl. Kgl. Bayer. Akad. Wiss. München. 1911:127–43. 1911.

[104] Dingler, H. Über Periodizität sommergrüner Bäume Mitteleuropas im Gebirgesklima Ceylons. Sitzungsber. Math.-Physical. Kl. Kgl. Bayer. Akad. Wiss. München. 1911:217–47. 1911.

in February or March. All stages of bud and leaf are said usually to occur in these trees.

An experiment similar to that performed by Dingler had previously been made by Wright[105] in Ceylon. He lopped trees of *Mangifera indica* and *Terminalia Catappa* in May and new leaves developed from July to September, with the result that no new leaves were produced on these trees in February and March when others of those species developed new crops of leaves. Some of the plants develop new leaves once or twice and others several times annually, and immature leaves may be found during every month of the year. Only a comparatively small percentage of the Ceylon trees are said to be deciduous. Some rapidly growing species were found to become defoliated at the end of the first year and others at the end of the second; while the more slowly growing ones may vegetate as evergreens until the close of the fifth or sixth year before losing their leaves. Usually, after a tree has once lost its leaves it loses them annually but some species are deciduous only in youth and become evergreen later. Some of the so-called evergreen trees are said to also lose all the leaves in occasional years before the new crop appears. In some species periods of sparse foliation occur two or three times per year and in others the foliage is more copious on alternate years. It is held that the absence of any very marked periodicity in the environment permits some plants to follow their inherent periodicity of growth, while the annual variation in the transpiration rate and atmospheric moisture are thought to be the cause of the deciduous habit of others.

These observations on foliar periodicity by Dingler, Wright and others seem to show that Dingler may be correct in his contention that leaf-fall is more dependent upon the normal duration of life of the leaves than upon the environment. However, if that should prove to be a fact, it would necessarily follow that certain plants are deciduous not because of the leaf-fall but on account of the failure of a new crop of leaves to develop before the old ones drop. Such a view centers attention upon the causes inhibiting growth rather than upon the causes of leaf-fall in the study of periodicity, a method of attack adopted by Klebs in the paper cited above.

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[105] Wright, H. Foliar periodicity of endemic and indigenous trees in Ceylon. Ann. Roy. Bot. Gard. Peradeniya 2:415–516. 1905.

It seems then that although trees having annual or more properly radial-growth rings are distributed all over the arborescent world, one or more factors of their envionment must be effective periodically in order that marked zonation occur. The more or less regular recurrence of cold or dry seasons are the factors usually noted in connection with periodically recurrent vegetative seasons, but doubtless any other recurrent environmental factor influencing growth may also affect zonation, e. g., periodic variation in the supply of inorganic foods as was suggested by Klebs.[106] It should be noted, however, that wood zonations resulting from recurrent dry periods of the tropics even in deciduous trees are not as marked as those occurring in temperate zones where the dormant period is chiefly due to seasonal variations in the temperature and where consequently a greater seasonal change occurs in the bark pressure.

The causes of the formation of radial-growth rings have been studied mainly in the north temperate zone and, therefore, explanations are largely based on the environmental factors that seem to be operative in that region. Seasonal changes in bark pressure, in the supply of metabolized food to the cambium, and in the rate of transpiration have been either separately or in partial combination advanced as explanations for the occurrence of the large-celled spring-wood alternating with small-celled summer-wood.

The bark-pressure hypothesis:—Sachs[107] seems to have been the first to suggest that the difference between spring and summer wood may be due to a difference in the bark tension or pressure obtaining in spring and summer. The idea was then tested experimentally by de Vries[108] with the result that Sachs' hypothesis seemed to have been sustained. The experiments by de Vries consisted in making some longitudinal slits in the outer bark of various trees in spring and of applying ligatures to the stems of others. On the following winter it was found that only about one-half as many cells had been produced under the ligatures as occurred on other parts of the past season's ring; while in the regions where the outer bark had been slit the number of

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[106] l. c.

[107] Sachs, von, F. G. J. Lehrbuch der Botanik. 1. Aufl. 1868, p. 409.

[108] Vries, de, H. Ueber den Einfluss des Rindendruckes auf den anatomischen Bau des Holzes. Vorläufige Mitlheilung. Flora. 33:97–102. 1875.

cells had become two to three times that produced in the normal portions of the ring. Similar experiments also showed that the amount of radial and tangential growth of cells differentiating from the cambium is inversely proportional to the pressure exerted on them. It also seemed that pressure acts as a selecting agent in determining the proportion of vessels to wood fibers; i. e. the greater the pressure the fewer the vessels and the more numerous the wood fibers to be produced. De Vries concluded therefore that bark pressure influences the rate of cambial division as well as the relative size cells may attain during differentiation. Since bark-growth follows the enlargement of the wood cylinder it was thought evident that bark pressure is greater toward the end of the radial-growth period than at its beginning. For these reasons de Vries held that a seasonal change in bark pressure is the chief cause of seasonal growth appearing as ''annual'' rings.

In some later experiments, while studying wound wood, he[109] found on lifting loose strips of bark with a knife on the concave side of young tree-trunks held in a bent position, and then tying it in place again in such a way as to prevent evaporation, that numerous large vessels developed in the new wood produced under the strips. He reiterated his former conclusion that bark pressure is an important factor in determining the size of wood cells and that it is largely responsible for the difference between spring and summer wood.

That bark tension does occur on enlarging stem structures had been shown by Kraus[109] as well as by Nördlinger[110] but neither of them secured quantitative results of value.

The influence of pressure on cambial activity and cell differentiation have since been investigated from various viewpoints and have led to different conclusions. Höhnel[111] found sharp-angled transverse displacements in the bast fibers of many Dicots at points where neighboring cells make an abrupt uneven

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[109] Vries, de, H. Ueber Wundholz. Flora. 34:2–8; 17–25; 38–45; 49–55; 81–88; 97–108; 113–21; 129–39. 1876.

[109] Kraus, G. Die Gewebespannung des Stammes und ihre Folgen. Bot. Zeit. 25:105–19; 121–33; 137–42. 1867.

[110] Nördlinger, H. Spannt die Baumrinde im Sommer nicht? Kritische Blät. Forst-u. Jagdwiss. 52:(1):253–55. 1870.

[111] Höhnel, von, F. Ueber den Einfluss des Rindendruckes auf die Beschaffenheit der Bastfasern der Dicotylen. Jahrb. Wiss. Bot. 15:311–26. 1884.

joint. Such transverse displacements or sharp double-bends were found in about two-thirds of the fifty to sixty species examined. They were especially prevalent in Urticaceae, Apocynaceae, Asclepidaceae, Linaceae, etc., while in other families the double-bends occurred only in certain genera. None were found in the Rosaceae including the pomaceous group, nor in the Tiliaceae and Cupuliferae.

It was held that the sharp bends are due to bark pressure, as indicated by the fact that in the plants in which these bends commonly occur the bast-fibers are but slightly or not at all lignified. Höhnel held that if the double bends were not due to growth or bark pressure they would not always appear at points in the fibers where joints or breaks occur in the cells of the surrounding tissues. The failure of the bends to become evident until after the tissues are fully differentiated was taken to indicate that bark-pressure becomes greater during the latter part of the differentiation period. It also seemed that in case of Urtica, Cannabis and Linum the bark pressure was often greater in the lower part of the stem than above, for the angular bends were frequently present on the fibers of the lower part while none occurred in the upper. The transverse displacements were found to be made up of two successive sharp bends which were noticeable in all layers of the wall. In many cases some of the layers were actually ruptured.

Krabbe[112] made extensive studies of bark pressure and tried to obtain some quantitative measurements. He increased bark pressure by encircling tree-trunks with a chain much like that now used on bicycles, except that it was wider. One end of the chain was fixed to an iron peg driven into the tree and the other ran over a pulley and had a weight pan attached. A piece of tin a little wider than the chain was placed about the trunk under the chain to distribute the pressure more evenly and to reduce friction. Weights were put into the pans in accordance with the determinations of bark pressure obtained before, and it was found that the bark pressure had to be doubled and even quadrupled before any influence on the size of the cells or the thickness of the yearly growth became evident.

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[112] Krabbe, G. Über die Beziehung der Rindenspannung zur Bildung der Jahrringe und zur Ablenkung der Markstrahlen. Sitzungsber. Akad. Wiss. Berlin 1882: 1093–1143. 1882.

The "normal" bark pressure was determined by stretching rings of bark over a smooth cylinder by means of weights until the bark had attained the length it had while still attached to the tree. In his later work[113] the rings of bark were straightened out and weighted at one end to determine the force required to stretch the bark to its former length, for it was found that the results obtained in this way were the same as those gotten with the more elaborate apparatus. The bark pressure of conifers was found to be usually under one-half an atmosphere and that of broad-leaved trees about twice as great. In case of conifers the pressure seemed to increase in fall on an average about 0.8 gm. per square millimeter of cross section, while the average of similar measurements on a number of broad-leaved trees indicated a decrease of pressure in fall equal to 12.5 gm. per square millimeter of cross section. He maintained that the breaking strain of bark is never reached by growth pressure. Bark pressure was found greatest in regions of most rapid radial growth, for instance on the side of excentric stems with the longer radius.

By using pressures from five to eight atmospheres the summer-wood type of radial growth was induced in spring on trees having comparatively little difference in the size of spring and summer-wood cells, while on trees having very marked differences between spring and summer wood it was practically impossible to induce the formation of the summer-size of cells in spring by increasing the bark pressure. In reducing the bark pressure by means of longitudinal slits in the outer bark in summer, typical spring wood vessels developed in trees which normally have only a slight difference between size of spring and summer wood cells; but in trees like Quercus and Fraxinus in which a marked difference occurs between spring and summer wood, the spring wood vessels could not be thus induced. Krabbe therefore concluded that bark pressure remains practically the same throughout the growing season and that changes in bark pressure could not be the cause of ring formation because it requires such a great increase to influence the size of the wood cells.

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[113] Über das Wachsthum des Verdickungsringes und der jungen Holzzellen in seiner Abhängigkeit von Druckwirkungen. Abhandl. Kgl. Akad. Wiss. Berlin. 1884. Anhang. 1:1–80. 1885.

Gehmacher[114] also performed some experiments in the increase and decrease of bark pressure on three to six-year-old trees and shrubs. The outer cortex was slit in February and nearby on the same stem a ligature of tightly wound wire was applied and the stem allowed to grow until the end of the season.

The number of cork cells varied inversely as the pressure and their radial diameter was decreased by 11% under increased bark pressure, while under reduced pressure an increase of 13% above normal resulted. A similar effect was noted on the cortical parenchyma cells except that both the radial and tangential diameters were decreased under increased pressure and the intercellular spaces were obliterated, while under reduced pressure the cells became globular and the intercellular spaces were increased in size above the normal. The difference between the thickness of the cortical parenchyma under increased and that under decreased pressure was enormous. In the wood the number of fibers increased and that of vessels decreased under added pressure, while the number of bast fibers was greatly reduced by increased pressure. Gemacher's conclusion was that it does not require the enormous differences of bark tension to influence the size of wood cells as had been maintained by Krabbe.

Hoffman[115] also investigated the influence of pressure on cell division and differentiation in the cambium of trees and concluded that the forces which contribute to the development of cylindrical stems rather than some other form are (1) bark tension and the consequent bark pressure, (2) radial-growth pressure, and (3) the passive resistance of the wood. Cambial division and growth are said to continue only as long as growth pressure exceeds bark pressure and it is thought that if bark pressure is equal on all sides the axis must either be or soon will become cylindrical on occurrence of continued radial growth. This is shown by the fact that angular young shoots become cylindrical on growing older. Even when the tension of the bark is the same all around a branch bark pressure may be different at different points, being considerable at prominences and

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[114] Gehmacher, A. Untersuchungen über den Einfluss des Rindendruckes auf das Wachstum und den Bau der Rinden. Stizungsber. K. Akad. Wiss. Wien. 88 Abt. 1:878–96. 1884.

[115] Hoffman, R. Untersuchungen über die Wirkung mechanischer Kräfte auf die Teilung, Anordnung und Ausbildung der Zellen beim Aufbau des Stammes der Laub- und Nadelhölzer. Inaug. Dissertation. Berlin. 1885. pp. 24.

perhaps zero or even negative in depressions. Among the numerous angular young twigs examined the greater pressure at the angles did not prevent the development of normal spring wood, but larger numbers of both spring and summer wood cells were produced in the depressions than on the ridges until the twig became cylindrical.

It was found that when a tree-trunk or branch presses against some non-yielding object or the bases of the component branches of a forked stem press against each other, radial growth is reduced on the side of contact when the pressure has reached a certain intensity and that the rays spread outward and eventually became parallel to the obstructing surface. The continuance of radial growth tends to separate or pull apart the components of a forked stem or widen the upper angle a branch makes with its axis. Branches thus firmly pressed against each other eventually fuse and the rays then come to radiate from the common center and further radial growth tends to result in a cylindrical, united structure. It was found that the callus developing at the cut end of a twig in water also conformed to the general law of the mechanics of radial growth in that its cross sections become semicircular with a rough outline; but the surface becomes smooth as tension is developed by further growth. When a rectangular piece of bark was cut from a tree the first division of the cambium in the formation of a callus is said to be by a radial wall or one at right angles to the wall formed under normal conditions. Further growth and division was also found to occur in accordance with the resistance to growth and resulted in a structure having its center at the place where the first cambial divisions took place. The rays in the bark on both sides of the piece cut out become diverted not only by the contraction of the bark at the time the piece was cut but also by the lack of surface growth in the bark surrounding the wound. The omission of surface growth is said to be due to the lack of accustomed tangential pull formerly exercised by the excised piece. Growth is resumed only after the callus bark has reached a tension comparable to that of the piece removed. This resulted in increased radial growth in the entire region influenced by the wounding, as shown by a count of the number of cells produced here as compared to that produced in other places. When the cambium was first freed from its normal bark pressure its cells took on isodiametric forms which were retained until the bark pressure became appreciable again and then reverted back to the elongate form normal to the species. It is held that the upper and lower edges of a wound do not produce callus as copiously as the lateral ones because of the lesser reduction of bark pressure, and the death of the cut cells which extend some distance above and below the wound.

From his experiments in which ligatures were applied to stems Sorauer[116] concluded that slow radial growth combined with high bark pressure results in twisted grain and that a reduction of bark pressure below normal not only induces more cells to form from the cambium, but cells having a greater diameter and a reduced length.

Newcombe[117] found that when external conditions prevent growth, the unfinished tissues remain unaltered and thin walled; that mechanical resistance or pressure prolongs the differentiation period, the cells remaining smaller and thinner walled.

The occurrence of numerous cocoons of bag-worms on various species of trees and the fact that the narrow silken bands by which they are attached to the twigs are often too strong for radial growth pressure to break, afforded von Schrenk[118] an occasion for a study of the effects of excessive pressure on radial growth. In most cases the silken bands encircling the twigs are burst early in the summer of the year following the time of the attachment of the bags. In some instances in which the ligatures were too strong to be ruptured by the thickening twigs the transfer of elaborated food was eventually checked and an enlargement developed on the distal side of the constricting band. In other cases the ligature was sufficiently distended by growth to permit of some food transfer and resulted in the formation of welts on both sides of bands. In some instances the pairs of welts fused above the ligatures and reestablished normal connection and pressure. In arbor vitae the wood fibers of the first

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116 Sorauer, P. Handbuch der Pflanzenkrankheiten. Dritle Auflage. 1:764–66. 1909.

117 Newcombe, F. C. The influence of mechanical resistance on the development and life-period of cells. Bot. Gaz. 19:149–57; 191–99; 229–36. 1894.

118 Schrenk, von, H. Constriction of twigs by the bag-worm and incident evidence of growth pressure. Ann. Rpt. Mo. Bot. Gard. 17:153–81. 1906.

year's growth were often found arranged at right angles to the axis, under unbroken bands.

In the latter part of the second summer following the attachment of the bags the portion of the twigs distad to the constriction had much starch in the bark rays and pith, while that on the basad side was practically devoid of it.

In hard-wood trees both bark and wood were found to have continued growing under unbroken bands though welts developed on both sides. The first wood cells formed under the ligatures were normal but those developing afterwards had a shorter radial diameter and thicker walls than those under normal pressure. The number of vessels appeared to decreaes in proportion to the pressure. The wood fibers developing under high pressure were found to have their long axis at right angles to the twig or parallel with the compressing band, and the rays were bent or buckled laterally unded pressure. It is held that the increased pressure induces the formation of smaller wood cells not because cambial division occurs before the cells have attained the normal size but because the pressure hinders their enlargement during subsequent differentiation.

A large number of tests made to determine the breaking strain of the bands from both conifers and broad-leaved trees showed it to be about 40 atmospheres; and, therefore, indicates that Krabbe's experimental results showing a growth pressure of 15 atmospheres are too low, since von Schrenk's observations show that the majority of the bag-worm ligatures are ruptured by the enlarging twigs.

An osmotic-pressure hypothesis.—In a paper on the development of pits in the wood cells of the Abietineae Russow[119] suggested another explanation of "annual" rings. He claimed that the bark pressure hypothesis of Sachs which de Vries endeavored to support by experiment, cannot account for the occurrence of growth rings in the wood because the last phloem cells of a season do not have a reduced radial diameter and on account of the fact that two rings may be induced by defoliating trees. The bark-pressure hypothesis is also held to be discredited by the occurrence of growth rings in the tropics where

[119] Russow, E. Über die Entwicklung des Hoftüpfels, der Membran der Holzzellen und des Jahresringes bei den Abietineen, in erster Linie von Pinus silvestris L., Sitzungsber. Naturfor. Ges. Dorpat 6: 147–57. 1884.

the bark is not distended by low temperature during a dormant season. In another paper he[120] added that in accordance with the bark-pressure hypothesis the wood cells in roots ought to be small while as a matter of fact they are large. On the other hand he held that the changes in the radial diameter of cells from spring to fall can easily be explained by assuming the presence in them of highly osmotic substances, which induce a high hydrostatic pressure and as a result give rise to large cells in spring, while toward the end of the radial-growth period the hydrostatic pressure in differentiating cells is reduced owing to a reduction of the osmotic pressure in them. By using solutions of glycerine as plasmolysing agents Wieler[121] found that osmotic pressure in herbaceous plants was less than that in the living wood and ray cells of trees where it ranged from 13 to 21 atmospheres. No difference was found, however, between the osmotic pressure in differentiating wood vessels and of that in the cambium cells. He thought that the walls of differentiating spring-wood cells are more distensible than those of summer wood owing to their lower cellulose content.

Seasonal variation in the available elaborated food as the cause of "annual" rings:—After years of intimate study of forest trees Hartig[122] concluded that since radial growth begins in spring under suboptimal environmental conditions and while the new leaves are very small or the buds are just bursting, the nutritive conditions of the cambium must also be suboptimal and for that reason the spring wood has thin cell walls. As the season advances the leaves attain full size which in connection with the accompanying seasonal changes are conducive to the manufacture of the larger quantities of organic foods which, according to Hartig, are responsible for the production of the thicker walled summer-wood cells. It is held that the chief difference between spring and summer wood consists essentially in the thickness of the cell walls and that the improvement in the nutrition of the cambium from early spring until the later summer is re-

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[120] Russow, E. Über den Inhalt der parenchymatischen Elemente der Rinde vor und während des Knospenaustriebes und Beginns der Cambiumthätigkeit in Stamm und Wurzel der einheimischen Lignosen. Sitzungsber. Naturfor. Ges. Dorpat. 6: 388–89. 1884.

[121] Wieler, A. Beiträge zur Kentniss der Jahresringbildung und des Dickenwachstums. Jahrb. Wiss. Bot. 18: 70–132. 1887.

[122] Hartig, R. Ein Ringlungsversuch. Allgem. Forst-u. Jagd-Zeit. 65: 365–73; 401–410. 1889.

sponsible for the occurrence of "annual rings." Hartig stated however, that the differences in the nutritive conditions cannot account for the change in radial diameter of wood cells nor for the presence of the larger proportion of vessels in spring wood, and maintained that the transpiration current determines their size. He suggested that the reason so little difference exists in the radial diameter of spring and summer wood cells of Populus, Salix, Acer, etc., is to be found in the fact that these trees continue producing new leaves throughout most of the radial growth period and because they have no duramen. Since the water current in trees with duramen is necessarily confined to the outer layers of wood its effects on cells differentiating from the cambium are thought to be more marked and therefore result in greater differences in the diameter of spring and summer wood cells, e. g. in oaks, etc. According to Hartig, then, "annual" rings are primarily due to the poor nutritive conditions of the cambium in spring being followed by a period of more abundant supply of metabolized food in summer, and secondarily to a decrease in the intensity of the transpiration current toward the end of the radial-growth period.

Wieler[123] came to a diametrically opposed conclusion regarding the differences in the nutritive conditions about the cambium in spring and summer. He thought that since the characteristics of "annual" rings lie in the type of wood produced in the early and late growing season and not in the succession of rings, the relation of different nutritive conditions to the formation of spring and summer xylem could be more easily determined experimentally with herbaceous than with woody plants. This was deemed permissible owing to the fact that in an examination of 54 species of herbs belonging to 21 families the characteristic reduction in the size of the xylem cells toward the end of the growing season as is typical of the "annual" rings of woody plants, was found in over half of them.

Seedlings of *Ricinus communis* were set into the soil of one-fourth to one-half liter pots in spring, well watered and given optimum light and temperature conditions, but they grew slowly and remained dwarfs. In early summer four of them were transplanted to the soil in a field and three of them into good soil in four liter pots. Those remaining in small pots were

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[123] l. c.

only about 27 cm. high in January and their stems about 21 mm. in circumference, while those in four liter pots were about 90 cm. high and 50 mm. in circumference. Those transplanted to the field became large plants with woody stems. Five dwarfed plants, which were subsequently transplanted to a forcing bed, had since made a rank growth and were retransplanted to four liter pots. They wilted but eventually recovered their turgidity, although the older leaves died.

Cross sections showed the xylem cells of the field plants to be larger and the vessels more numerous than in those retained in the small pots. In the plants transplanted to the field the xylem cells around the pith were small and were surrounded by larger ones toward the periphery. In case of those transplanted to four liter pots the same inversion of the normal position of large and small celled xylem occurred, but in addition the outermost rows again had a much reduced radial diameter. In the field plants which had been retransplanted to pots the outermost cells also had a reduced radial diameter and thick walls while within them was a zone of large, thin-walled cells which had apparently been formed just before the last transplanting and as a result their walls remained unthickened. Similar results were also obtained with *Helianthus annuus*. Wieler concluded from these experiments that the abundant supply of metabolized food to the cambium is the most important factor in the production of spring wood and that the shortage of such a food supply induces the formation of summer wood, and that therefore "annual" rings of trees are due to an abundant supply of organic food to the cambium in spring and a reduced supply in summer.

Lutz[124] was of the opinion that when the food supply to a rapidly dividing cambium is comparatively low while water is abundant the cells become large and thin-walled as is characteristic of spring wood, while if the food supply is good and the water is low the cells become small and thick-walled as in summer wood.

In a later paper Wieler[125] reiterated his former conclusions though he admits his inability to prove that the small radial

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[124] l. c.

[125] Wieler, A. Ueber die Abhängigkeit der Jahresringbildung von den Ernährungsverhältnissen. Allgem. Forst-u. Jagd-Zeit. 67: 82–89. 1891.

diameter of summer-wood cells results from a reduced supply of food to the cambial region; nevertheless, it is held to be a more likely contention than that maintained by Hartig to the effect that summer-wood results from an increase in the supply of metabolized food.

In this paper Wieler cited similar experiments by Sachs[126] in support of his conclusions, although Sachs noted that the frequent addition of abundant nutrient solution failed to induce more growth in small pots. Sachs held the dwarfing in small pots to be due to a crowding of the root system into mats in such a way as to greatly impair their absorptive functions.

The relation of rest and food supply to the production of wood rings:—Mer[127] held that the winter rest of the cambium and its consequent great activity in spring in connection with the abundance of plastic materials at that time are the causes of the production of large-celled spring wood. The cell walls of spring wood are thought to remain relatively thin because the food transfer through such a thick differentiating zone of cells is comparatively slow, and the thick walls of summer wood cells are assumed to be due to slow rate of cambial division or to the thinness of the differentiating zone and consequent ready access of organic food to its cells. The sudden and considerable decrease in the radial diameter of the peripheral few rows of wood cells in a year's growth is held to be due to an arrest of their development as a result of enfeebled cambial activity rather than to an increase of bark pressure as maintained by Sachs, de Vries and others.

A summary and comparison of the hypotheses:—The work of Kraus, de Vries, Nördlinger, Detlefsen, von Höhnel, Gemacher, Hoffman, Kny, Newcombe, von Schrenk, and Sorauer, have made it apparent that pressure on the cambium affects the rate of cell division as well as the size differentiating wood cells may attain, but owing to the fact that no method has as yet been developed by means of which quantitative measurements of bark pressure can be made it is impossible to determine just what relation bark pressure has to the production of ''annual'' rings.

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[126] Sachs, von, F. G. J. Vorlesungen über Pflanzenphysiologie. Leipzig. 1882. p. 623.

[127] l. c.

The different degrees of hydrostatic pressure assumed by Russow as the cause of the difference between spring and summer wood has apparenty also been implied by Hartig, Mer and others in speaking of growth force, etc., but even more than in the former case do the few qualitative tests need to be replaced by quantitative measurements before the validity of the idea could be tested.

Hartig has collected a mass of observational and even some indirect quantitative data that seem to support his hypothesis that the relative abundance of elaborated food determines the thickness of cell walls and that the relative intensity of the transpiration stream determines the length of the radial diameter of wood cells, but the experiments of Jost, Lutz and others show that although food and water may be present in great abundance very little or no radial growth occurs when terminal growth is prevented.

Wieler's hypothesis that the abundance of metabolized food in the cambial region in spring induces the formation of spring wood and its reduction, summer wood is also lacking in that it does not account for the cessation of radial growth on the removal of the elongation structures. Besides, the experiments with which he assumes to have made his contention probably involved too many unknown variables to afford even a satisfactory test of the hypothesis.

The results obtained by Morgulis[128] in his experiments in alternately feeding and starving salamanders tend also to make one skeptical regarding the value of the hypotheses of both Hartig and Wieler as explanations of ring formation because Morgulis found "That the rate of growth is independent of the amount of nutrition" and that "The impulse to grow plays the leading part" and "determines the degree of utilization of the nutriment." Finally, he found too that "From all that has preceded, the conclusion can be drawn that periodic starvation is more detrimental to the organism than acute starvation followed by a liberal supply of food. In the former case the individual remains below the level of the normally fed animals; in the latter case, on the contrary, provided the inanition has

[128] Morgulis, S. The influence of protracted and intermittent fasting upon growth. Amer. Nat. 47: 477–87. 1913.

not been carried too far, the restorative process may go even beyond the limit attainable under normal conditions."

Since Hartig laid especial stress on the difference in the thickness of cell walls rather than the size of cells as the essential difference between spring and summer wood his secondary factor, the relative intensity of the transpiration current, would come in for first consideration because it is claimed to regulate the size of cells. It seems possible that the full report promised by Jaccard[129] on the tree-trunk as a shaft of equal water conductance may throw more light on Hartig's idea.

The possible relation of enzymes to the formation of "annual" rings:—In cases of this kind in which the hypotheses are so numerous and the advocates of each can marshal at least a portion of the observed facts in support of their views the truth usually lies somewhere between them, and each conflicting explanation will eventually contribute certain fragments to a theory that will account for the known facts. The time for such a theory has not yet come. However, since none of the proposed hypotheses gives promise of becoming such an explanatory theory it may be pardonable to submit yet another with the hope that the viewpoint thus suggested might lead to a new attack on the problem.

From our present knowledge it seems that to be of any value as a basis for work or a stimulus for the further study of radial growth rings such an hypothesis must, by using all known and some probable but undetermined facts explain how it is that wood cells have a smaller radial diameter in summer than in spring and why vessels are often wholly lacking in the later summer wood.

It has been shown that an "annual" ring consists essentially of a sheath or ring of wood produced during one more or less continuous radial-growth period and that it is made up of two types of wood which may merge gradually into each other or join at a rather abrupt line. That portion of the ring developed in "spring" or during the early part of a new elongation-growth period has larger cells than that produced in "summer" or after the closing of the first elongation, following the principal dormant season. In the case of trees in temperate zones and many of those in the tropics which produce new leaves near-

[129] l. c.

ly throughout the vegetative season the growth rings are not very marked though they are usually apparent. Generally the most reliable criterion for distinguishing the rings is the reduction in the radial diameter of at least the last row or two of wood cells; yet in the tropics histological distinctions are said to be practically absent in some trees, and their rings may only be distinguished by slight demarking lines.

The work reviewed in this paper has shown that the environmental factors which control elongation growth also influence radial growth and that ordinarily the prevention of elongation by the removal of vegetative points hinders growth in thickness even when the environmental conditions are optimal and the food and water supply abundant. Klebs[130] assumed, in fact, that large quantities of organic foods accumulating in plants inactivates the enzymes concerned in elongation and therefore brings about a cessation of growth in length. According to him a timely increase in the water and inorganic nutrients may reactivate or prevent inactivation of the growth enzymes and thereby shorten or eliminate the dormant period.

With such a precedent one may also assume the presence of enzymes which incite and maintain radial growth since there are a number of phenomena to be noticed in connection with growth in thickness that support such an assumption, as may be gathered from the following papers.

In an investigation on the reserve food in seeds Reiss[131] found that cellulose is laid down on the inner side of cell walls of many seeds and that it is largely redissolved on germination. Schulze[132] made a similar study of lupine seeds and found convincing evidence that the inner layers of the cotyledonary cell walls are used up during germination. It seemed that the dissolving part of the walls is a hemicellulose which gives rise to galactose and arabinose on hydrolysis. Grüss[133] also noted the occurrence of the hemicelluloses, galactan and araban, in plant

[133] Grüss, J. Ueber Lösung und Bildung der aus Hemicellulose bestehenden Zellwände und ihre Beiziehung zur Gummosis. Biblio. Bot. 39. 1896. pp. 14.

[130] l. c.

[131] Reiss, R. Ueber die Natur der Reservecellulose und über ihre Auflösungsweise bei der Keimung der Samen. Ber. Deut. Bot. Ges. 7: 322–29. 1889.

[132] Schulze, E. Ueber die Zellwandbestandtheile der Cotyledonen von Lupinus lutens und Lupinus angustifolius und über ihr Verhalten während des Keimungsvorgangs. Ber. Deut. Bot. Ges. 14: 66–71. 1896.

cells, and that they may be dissolved or converted into gum by enzymes. Potter[134] called attention to the presence of an inner cellulose layer in the xylem cells of many normal trees, and to its especial abundance in the wood fibers of Quercus, Fagus, Aesculus, Salix, Ulmus, Alnus, and Betula. He found that after keeping wood in water during some days cellulose linings became apparent in many cells in which none had been noted before the water treatment.

Du Sablon[135] concluded that when starch disappears in late fall much of it is converted into reserve cellulose which is deposited on the inner side of wood-cell walls. In some cases this lining was found to be comparativey thick and occasionally it even had folds extending into the lumen of cells. It is said to be readily soluble in dilute hydrochloric acid.

Schellenberg[136] made a more thorough study of the deposition and partial solution of hemicellulose in the wood and bark of trees. He found a hemicellulose lining on the walls of fibers in both spring and summer wood of *Aesculus Hippocastanum*, Betula and other trees but it was not dissolved in spring. Since similar hemicellulose linings in the cells of the phloem and cortical parenchyma were found corroded in spring he concluded that the lining did not dissolve in the fibers because protoplasm was absent there. In the wood fibers of Vitis and *Robina Pseudacacia* he noted the occurrence of especially thick hemicelulose layers in well matured wood and of much thinner ones in those of immature wood. The protoplasm remains alive in the wood fibers of Vitis and he accordingly found the inner layers corroded and dissolved in spring. He also found the same solution of the inner unlignified layers in the bast fibers and cortica lparenchyma and collenchyma of *Fraxinus excelsior*. Usually from a third to half of the unlignified layer in the cortical parenchyma is dissolved when the buds open. He was of the opinion that the deposition of hemicellulose in the bark parenchyma continues after the leaves fall.

From these papers it is evident that a hemicellulose dissolving enzyme is active during the early part of a vegetative sea-

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[134] Potter, M. C. On the occurrence of cellulose in the xylem of woody stems. Ann. Bot. 18: 121–40. 1904.
[135] l. c.
[136] Schellenberg, H. C. Ueber Hemicellulosen als Reservestoffe bei unsern Waldbäumen. Ber. Deut. Bot. Ges. 23: 36–45. 1905.

son and that such an enzyme is not present or is inactive in the latter part of the growing period as indicated by the fact that hemicellulose is deposited in both the wood and bark at that time. Sanio[137] found that in *Pinus silvestris* lignification did not occur in spring wood until after the deposition of the secondary thickening had been completed, that it began at the angles of the cells and then involved the radial walls and later the tangential walls. In the summer wood, however, the primary walls were found to have lignified before the deposition of the secondary thickening began, and it occurred in cells which were only a few removed from the cambium. The final composition of the cell walls of spring and summer wood seem also to differ, for according to Wieler,[138] the walls of spring wood contain a lower percentage of cellulose than those of summer wood.

If the deposition and lignification of cellulose are in any way dependent upon enzymotic action, there must be at least two enzymes concerned because the two processes appear to be independent of each other as indicated by Sanio's observations. It is evident that either of the processes would necessarily impede or check further enlargement of cells differentiating from the cambium. It, therefore, appears permissible to assume that the enzymes involved in the solution of hemicellulose and the tardiness of the lignification process in spring are important factors in permitting the development of larger wood cells in spring than those produced in summer, when the cellulose dissolving enzymes are inactive and lignification occurs so quickly after a cell is formed that in some cases it takes place even before secondary thickening has begun. The experiments by Jost and by Lutz also give support to the idea that radial growth is largely controlled by enzymotic activities which are somehow dependent upon the process of terminal elongation. Perhaps the enzymes concerned are liberated or activated in enlarging and bursting buds in different parts of trees and are carried downward in the metabolized food, or possibly enzymes produced in the enlarging buds simply initiate certain activities which are transmitted without the further aid of the enzymes as was assumed by

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[137] Sanio, K. Anatomie der gemeinen Kiefer (Pinus silvestris L.). Jahrb. Wiss. Bot. 9: 66–68. 1873.

[138] l. c.

Fick[139] regarding the action of the enzymes which coagulate blood and milk.

The fact that stems and branches of trees are more pliable and easily bent while in the midst of active spring growth than they are at any other time, indicates that perhaps some enzymotic softening of the mature wood occurs during the period of most active growth. The upward bending of a branch on a decapitated conifer also argues for the presence of some softening agent during the time of most vigorous growth because of the fact that such branches often bend in response to gravity at places where lignification had previously occurred. In other words, it seems that one of the most important factors in the production of large wood cells in spring and smaller ones in summer may be the presence of enzymes which retard lignification and prevent rapid thickening of the walls and thereby permit growth or hydrostatic pressure to develop large cells in spring; while the absence or inactive condition of those enzymes induces rapid thickening and early lignification of the walls in summer and thus checks the enlargement of summer-wood cells.

It may be that the idea of growth force expressed by Detlefsen, Mer and others as well as "the impulse to grow" emphasized by Morgulis imply the same sort of notion as that advanced in the above scheme regarding the possible relation of enzymes to ring formation, but in any case the hypothesis is only a guess based on rather suggestive indirect evidence. Mer's conclusion that the winter rest of the cambium induces its greater activity in spring seems to have something in common with the outcome of some feeding experiments by Morgulis, to the effect that in subjecting salamanders to alternate periods of fasting and liberal feeding a greater growth resulted than by more frequent and abundant feedings. A theory to account for wood rings must also make use of the evidence brought out regarding the effect of variations in bark tension both longitudinal and transverse, as well as of the influence of the transpiration stream as suggested by Hartig and more recently elaborated by Jaccard in his discussion of the distribution of radial growth. It should be remembered, however, that transpiration is perhaps greater during the time summer-wood is formed than it is while spring wood develops; to say that larger cells are produced in spring to meet the higher water requirements of the approaching summer explains nothing.

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[139] Fick, A. Ueber die Wirkungsart der Gerinnungsfermente. Archiv. Gesam. Physiol. Mens. Thiere. 45: 293–96. 1889.

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NOTES ON PARASITIC FUNGI IN WISCONSIN—I.

J. J. DAVIS.

These notes are intended to be supplementary to "A provisional List of Parasitic Fungi in Wisconsin" published in Transactions of the Wisconsin Academy of Sciences, Arts and Letters. Vol. XVII, pt. 2, pp. 846–984.

Plasmopara humuli Miyabe & Takahashi. This was collected on wild *Humulus Lupulus* growing along the river bank at Racine in 1909–10 since which time the station has not been visited. The following notes of this fungus were made at Racine: Spots small, angular at first, limited by the veinlets, brown-red or purplish above, below of a darker green than the leaf, giving the "water soaked" appearance. The spots are surrounded by an indeterminate yellowish discoloration especially early in the season, less marked as the leaves become firmer, and finally assume the lethal brown with the death of the tissues included. Conidiphores hypophyllous, grey, 175–325x5–6½μ with usually two lateral branches each of which is about equal in development to the terminal portion and 1–3 times branched, ultimate branchlets tapering, subacute; conidia fuligineous tinted, elliptical, somewhat acute at each end, furnished with an apical papilla of dehiscence, 20–33 x 12–17μ, usually about 26 x 15μ; oospores scattered in the leaves; oogonia irregularly thickened, brown, subglobose, 36–40μ long, oöspores filling the oögonia 30–33μ long.

Asterina plantaginis Ellis. This is referred to *Mycosphaerella* by Theissen *(Ann. Mycol. 10:2:196.* (Apr. 1912).

Asterina rubicola Ell. & Evht. This is described by Theissen in the same communication (p. 195) but no new combination is proposed.

Gnomoniella fimbriata (Pers.) Sacc. This was inserted in the provisional list because of an immature specimen in the herbarium of the University of Wisconsin which is perhaps of this species. It was collected at Osceola by E. Sheldon in 1892.

Phyllosticta destruens Desm. In writing the provisional list I followed Ellis & Everhart *(North American Phyllostictas, 40)* in referring to this species specimens on *Prunus virginiana* and also on *Amelanchier*. The former has been described under the name *Phoma virginiana* Ell. & Hals. (Journ. Mycol. 4:8. (1888)) the latter as *Phyllosticta innumerabilis* Pk. (Bull. Torr. Bot. Club. 36:336 (1909)). Specimens on *Amelanchier* were distributed under the name *Phyllosticta destructens* Desm. in *Fungi Columbiani continued 1447.* I have seen no European specimens of *Ph. destruens* Desm. which is said to occur on *Celtis* as well as *Prunus* and to have epiphyllous pycnidia, but I infer that Mr. Ellis had good reason for using that name. Before the list was printed I removed *Amelanchier* as a host of *Phyllosticta destruens* Desm. with the intention of inserting *Ph. innumerabilis* Pk. an intention which I failed to carry out, so that *Amelanchier* as bearing the *Phyllosticta* appears only in the host index. Morphologically I see no distinction between the fungi on the two hosts.

In the provisional list of parasitic fungi in Wisconsin Patouillard is given as the author of the binominal *Protomyces andinus* as is done in the *Sylloge Fungorum.* An examination of Patouillard's paper however shows that it was published as *Protomyces andinus* Lagh. sp. nov. Lagerheim, not Spegazzini, collected the type material in Ecuador, not Chili.

Phyllosticta mulgedii Davis, a name that was proposed in the 4th supplementary list (No. 709), was omitted from the provisional list. The fungus has not been collected again and is probably one of the *Phomae* that have been described as occurring on the leaves of *Compositae.*

Phyllosticta desmodii Ell. & Evht. This was described *(Journ. Mycol. 5:* 146: 1889) from a single small collection in Walworth Co. Much better material has been collected at Madison on *Desmodium canescens.* The pycnidia are epiphyllous, brown, subspherical, 125–160μ in diameter; sporules oblong, often somewhat narrower in the middle, ends rounded, conspicuously 2–4 guttulate, 6–12x3μ. The appearance of the sporules suggests that later they may become septate.

Phyllosticta cruenta (Fr.) Kickx. The reference of this species to *Macrophoma* as proposed by Ferraris *(Ann. Mycol. 10:3:288* (Jn. 1912)) would make a generic distinction between the two forms that were given as varieties in the provisional list because the globose sporules of *Ph. pallidior* Pk. are only about 10μ in length, although they equal in content the longer and narrower sporules of the type of *Ph. discincta.*

Ascochyta pisi Lib. has been shown by R. E. Stone to be a conidial form of *Mycosphaerella pinodes* (Berk. & Blox.) Niessl *(Ann. Mycol. 10*:564 *et seq.* (Dec. 1912). Also R. E. Vaughan, *Phytopathology 3*:71 [1913].

Actinonema rosae, (Lib.) Fr. Diedicke calls this *Marssonina rosae* (Lib.) Trail *(Ann. Mycol. 10*:146 (Apr. 1912)). F. A. Wolf has developed the ascosporous stage which he refers to the *Microthyriaceae* and makes the type of a new genus and calls it *Diplocarpon rosae* F. A. Wolf. *(Bot. Gaz. 54,* 231 (Sept. 1912)).

Septoria nubilosa Ell. & Evht. (Proc. Acad. Nat. Sci. Phil. 1891, p. 76) which was founded on Wisconsin material on *Helenium autumnale* has not been included in the Wisconsin lists because it is merely a form of *Septoria helenii* Ell. & Evht. in which the spots are not well developed. The type was collected on the north side of plants bearing typical *S. helenii* and was sent to the authors merely to show the variation.

Septoria ribis Desm. Some of the specimens that I have referred to this species are perhaps *S. grossulariae* var. *longispora* Ferraris *(Ann. Mycol. 10:291).* Typical *S. grossulariae* (Lib.) West. I have collected but once.

Septoria saccharina Ell. & Evht. Specimens from Price Co. bear sporules about 30x2½μ. The *Acer*—inhabiting fungi, having triseptate sporules borne in acervuli and varying in length from 20–70μ and in width from 1½–5μ seem to me to constitute a group the relation of the members of which can be determined by inoculation methods only. The form with short and thick sporules has been called *Ascochyta aceris* Lib. and later

Phleospora aceris (Lib.) Sacc. and with this have been included narrower spored forms but usually the latter have been referred to *Septoria.* Diedicke has recently referred the European forms with sporules 3μ or less in thickness to *Cylindrosporium,* recognizing three species. (*Ann. Mycol.* 10:486 (Oct. 1912)). *Septoria saccharina* E. & E., however, while producing similar sporules develops pycnidia in definite arid spots but *Cylindrosporium saccharinum* Ell. & Ev. agrees with the form on *Acer rubrum* which was recorded in the "provisional list" under the name *Phleospora aceris* (Lib.) Sacc.

Septoria musiva Pk. The specimens of Septoria that have been collected on *Populus* in Wisconsin may be divided into groups as follows:

1. Spots subcircular to subangular, black becoming white and arid except the peripheral portion, 3–5 mm. in diameter; pycnidia epiphyllous, superficial-collapsing, hemispherical in section, about 100μ in diameter; sporules cylindrical, curved, obtuse, 3(2–4) septate, 25–60 x 2–3μ. On *Populus balsamifera.*

2. Similar to the above except that the central portion of the spot becomes alutaceous or cinereous instead of white and the pycnidia are more scattered and lie deeper. Also on *P. balsamifera.*

3. Spots subcircular to angular, limited by the veinlets, at first brown, becoming grey by the loosening of the cuticle, 1–3 mm. in diameter, becoming confluent into larger areas, ½–1 cm. in diameter; pycnidia innate, discharging on either surface but usually below, having a thin but distinct wall and a large opening, 70–100μ in diameter; sporules cylindrical, curved, obtuse, 3(2–4)-septate, 25–65 x 2–3μ. On *Populus deltoides.*

4. Spots roundish to irregular and angular, dark brown above becoming grey with age, light brown below, 2–5 mm. in diameter, often confluent; pycnidia hypophyllous, punctiform; sporules cylindrical, curved, obtuse, 3–5 septate, 45–65 x 3μ. On *P. balsamifera.*

5. Spots angular, blackish brown above, paler below, becoming lighter and mottled with age, ½–1 cm. in diameter; pycnidia scattered, innate, thin walled; sporules filiform, narrowed to one end, 3–6 septate, 40–70x1½–2½μ. On *Populus tremuloides.*

In the provisional list all of these forms were included in *Septoria musiva* Pk., although group 5 may prove to be distinct, but one can hardly decide that on morphological grounds without an abundance of material. I find this in Wisconsin only to the north and with few pycnidia. Much the best specimens that I have seen were collected at North Yakima, Wash. (Wis. Acad. Sci. Arts & Lett. *15*:778).

In Farlow's Host Index, *Populus balsamifera* is given as a host of *Septoria salicina* Pk. I presume that this refers to what I have called group 1. This form looks quite distinct but it merges into group 2 and that again into group 3 in a way that makes it difficult to draw a line of separation, while the characters of the sporules are identical. *Septoria salicina* Pk. differs in its uniseptate sporules. Of *Septoria populi* Desm., which has uniseptate sporules, I have seen no American specimens. *Fungi Columbiani 2873,* issued under this name seems to be the same as *2872* which is labeled *Septoria musiva* Pk. On neither have I found a *Septoria.* I may mention that *F. Col. 1587* on *Populus tremuloides* collected by J. B. Ellis at Newfield, N. J. and issued as *S. musiva* Pk. bears *Marssonina rhabdospora* (E. & E.) Magn. at least in the two copies which I have seen. *F. Col. 3486* on *Populus balsamifera* collected at St. Johnsbury, Vt. by W. P. Carr and issued as *Septoria populi* Desm. is of the form with black bordered alutaceous spots that I have placed in group 2. *Pacific Slope Fungi 1723* on *Populus Fremonti* collected in California by Copeland and issued by Baker as *Septoria populi* Desm. is somewhat intermediate between groups 2 and 3. *Fungi Columbiani 1257* on *Populus angustifolia* collected at Golden, Colorado, by Bethel, and issued as *Septoria populi* Desm. has subcircular spots of a yellowish white or sordid white color with an irregular grey-brown border 2–4 mm. in diameter; the pycnidia are hypophyllous, broad and collapsing; the sporules continuous 23–35 x 3½–4μ. While this does not correspond with *S. populi* Desm. it is different from any *Septoria* on *Populus* that I have seen and judging from the single specimen may prove to be distinct. *Cylindrosporium oculatum* Ell. & Evht. on *Populus deltoides* (Put-in-Bay, Ohio) has hemispheric-superficial pycnidia and obtuse sporules 30–50 x 3μ becoming 3 or more septate. This forms circular grey to sordid spots about ½ cm. in diameter with a narrow dark border. I would include it in *Septoria musiva* Pk. as representing forms 1 and 2 on *Populus deltoides.* Specimens on this host collected at Ithaca, N. Y., by Higgins (com. Bartholomew) bear both this and form 3 on the same leaves.

After this was written a collection was made from the examination of which the following characters were noted: spots angular-suborbicular, at first brown with a narrow darker margin, then grey and finally mottled with small angular cream colored areas, sometimes confluent, 2–3 mm. in diameter; pycnidia mostly hypophyllous and inconspicuous, 65–75μ in diameter; sporules, hyaline, filiform, acute, 3–6 septate, 38–60 x 2½–3½μ. On *Populus grandidentata*. Devils Lake, Wisconsin, Aug. 6, 1913.

In this connection a still more recent (Aug. 21, 1914) collection on *Populus deltoides* is of interest. *Phyllosticta populina* Sacc. is said to occur in association with *Septoria populi* Desm. in Europe. Having made a collection of the former at Prescott the associated *Septoria* was examined with some interest. The spots are orbicular, cinereous with a narrow dark margin and resemble those of form 2 except in the grey color which in the older spots changes to white. On some of the leaves are small angular, confluent spots like those of typical *Septoria musiva* Pk. Of the first mount from this material it was noted "sporules mostly 18–22 x 2–3μ, 1–2 septate with occasional longer ones up to 48μ and 3-septate"; of another mount "30–45 x 2–3μ, 2–3 septate". This seems to connect with the forms described above and suggests that there is a widely variable species of *Septoria* occurring on *Populus* in both America and Europe. *Septoria candida* (Fckl.?) Sacc. I have not seen, but the description indicates that it might readily fall in with the American forms.

Cercospora geranii Kell. & Sw. Of a specimen collected at Blue Mounds the following notes were made. Hyphae usually straight, slightly colored, often toothed, 25–75 x 6–7μ; conidia hyaline, cylindrical, usually more or less curved, obtuse, becoming pluriseptate, 100–165 x 4–5μ.

Cercospora subsanguinea Ell. & Evht. is sometimes devoid of color and the obtuse conidia sometimes divide in the middle. It appears to be more nearly a *Ramularia*.

Gloeosporium fragariae (Lib.) Mont. My notes of the measurements of the sporules of the fungus referred to this species range from 12–24 x 4–5μ. It was collected at Spooner.

Gloeosporium ribis (Lib.) Mont. & Desm. As it occurs in Wisconsin this usually has the characters of the forma *ribis nigri americana* Sacc. The sporules sometimes reach 30μ in length.

Gloeosporium tremuloides Ell. & Evht. 2nd suppl. list no. 526 was omitted from the provisional list because of the belief that the species was founded on imperfectly developed material of *Marssonina castagnei* (D. & M.) Magn. which occurs in atypical forms in Wisconsin. Oudemans proposed the variety *monili-ferae* in which the acervuli are amphigenous although more abundant above. In Wisconsin they are often hypophyllous only and the sporules are often but 12–15μ long. *Marssonina brunnea* (E. & E.) has been omitted, being considered, perhaps erroneously, a form of *M. castagnei.*

Ramularia plantaginis Ell. & Mart. In the description of this species the spots are said to be minute. Specimens on *Plantago Rugelii* collected at Madison in September have spots up to 3 cm. in diameter. Conidia appear also on the calyces.

Ramularia alismatis Fautrey. This was reported in the third supplementary list under the name *Ascochyta alismatis* (Oud.) Trail. Dr. R. A. Harper has kindly compared Wisconsin material with the type of *Ascochyta alismatis* Ell. & Evht. in the Ellis herbarium and finds them to be the same. The very short undifferentiated conidia-bearing hyphae makes this an atypical *Ramularia.* It is not unlikely that *Septoria alismatis* Oud. is of the same character. The spots usually have a slight eminence in the center as if a pycnidium lay beneath. (See Diedicke, *Ann. Mycol. 10*:479).

Ramularia uredinis (Voss) Sacc. This is the fungus recorded in the supplementary and 3rd suppl. lists no. 330 under the name *Fusarium uredinum* E. & E. The tufts are sometimes pink or even testaceous. My measurements of the conidia, which are in branched chains, are from 7–17x3–4μ.

Ustilago osmundae Pk. This has been collected on *Osmunda regalis* in Washburn and Burnett counties. I have not been able to follow the author of the species in his reference of it to *Mycosyrinx.* (New York State Museum; Report of the Botanist 1911, p. 43). When the fungus is present each frond arising from the rhizome bears the smut or else is sterile.

Ustilago lorentziana Thuem. which occurs at Madison on *Hordeum jubatum* and which was recorded in the 4th supplementary list seems to have been omitted from the provisional list.

Entyloma linariae Schroet. var. *veronicae* Wint. The newly formed spores of this smut were found to germinate readily in May but to gradually lose the power as the season progressed as had been found to be the case with *E. floerkeae* Holw. (2nd suppl. list, No. 487). The promycelial spores are usually two (1–4) in number, 15–20 x 3μ.

Material wintered outdoors (May to May) germinated the following spring in the same manner.

Additional Hosts.

Synchytrium aureum Schroet.

In September, 1912, this was found at Millston, Jackson county on *Lycopus virginicus, Lysimachia terrestris* and leaves of blackberries that I have referred to *Rubus hispidus* and *Rubus villosus.* The infection was sufficient to indicate that each of these plants are normal hosts of the organism in that locality, *Rubus villosus* being least affected. No success attended special efforts to find other hosts. In 1913 it was collected at Athelstane, Marinette Co., on *Rubus hispidus* but on no other host. In 1892 *Synchytrium* occurred rather abundantly in a bit of woodland near Berryville on *Viola pubescens* and *Geum canadense* and during the same season it was collected at Somers, but a few miles distant, on *Ranunculus recurvatus.* The infection of the latter was limited and I have not seen it since on this host. It was collected again at Berryville in 1894 soon after which the station was cleared and put under cultivation. In 1902 a collection on *Viola pubescens* was made at the Somers station. In 1907 considerable infection of the same host was observed at a station intermediate between the other two and during the same season very limited infection of *Prenanthes alba* at this station and of *Pedicularis canadensis* near Racine was observed. The infection of the two latter hosts appeared to be accidental and temporary, the organism failing to get a permanent foothold. At Millston some of the affected leaves of *Lycopus* bore considerable hypertrophies often surrounded by purple discoloration but usually there was little distortion of the hosts, even when the sori were numerous and aggregated, the pressure being into the mesophyl which was sometimes torn from the epidermis in the area surrounding the gall.

The common factors which make for susceptibility in these various hosts are not apparent to me.

Septoria astericola Ell. & Evht. on *Aster puniceus.* In the specimen on this host the spots become lead color with a dark border. The largest spots are 1 cm. long. The pycnidia are epiphyllous, about 80μ in diameter and the sporules 23–33 x 1μ. Collected at Lake Mills, Oct. 19, 1912.

Gloeosporium saccharinum, Ell. & Evht. Specimens on *Acer spicatum* collected at Spooner have circular spots of a pale olive color with a darker border; the largest sporules are 7x3μ. The fungus often developes on subcircular spots of a tan color on *Acer Saccharum.*

Cercospora caricina Ell. & Dearn. My notes of a specimen on *Cyperus filiculmis* collected at Madison, Aug. 12, 1912, are as follows: Hyphae 3–8 in a tuft, brown, somewhat nodulose, often denticulate at the apex, 50–80x3–4μ; conidia hyaline, obclavate-cylindrical, straight or curved, becoming pluriseptate, 65–100x 3–4μ. On bracts and culms, spreading from above downward. *Cercospora caricina* Ell. & Dearn. is described as having hyphae 15–25 x 3–3½μ and conidia 34–73 x 3μ, but I have specimens on *Carex* in which the hyphae and conidia equal those noted on *Cyperus. Cyperus Houghtonii* which was tentatively given as a host in the 4th suppl. list should not have been omitted from the provisional list.

Cercospora ceanothi Kell. & Swingle. On *Ceanothus americanus.* Madison. In one of the collections on this host the fungus is particularly well developed, the conidiophores being 20–45x 4–5μ and the attenuate conidia 80–150 x 4–6μ. A collection made in the same locality two weeks later agrees with the description of *Cercospora fuliginosa,* E. &. E. the conidia being darker, cylindrical and 30–80 long. It is probable, therefore, that the descriptions of *C. ceanothi* Kell. & Swingle and *C. fuliginosa* Ell. & Evht. were drawn from different states of the same fungus. The former is the prior name and the latter is antedated by *C. fuliginosa* Ell. & Kell. on *Diospyros* (1887) for which reason *C. MacClatchieana* Sacc. & Syd. was substituted.

Additional Species.

Leptosphaeria folliculata Ell. & Evht. var. OXYSPORA n. var. On *Carex gracillima.* Price Co. Sept. 9, 1911. Differs from the type in the somewhat narrower asci (*ca.* 50x8μ) and especially in the triseptate acute ascopores (*ca.* 15x3μ). On the comparatively narrow leaves of this host the perithecia are borne on dead apical areas at the bases of which there is often evidence of primary spotting and confluence. I am indebted to Dr. R. A. Harper for comparison of this with the type in the Ellis herbarium at the New York Botanical Garden. It is not unlikely that sufficient material would connect these forms with *L. caricicola* Fautr. and *L. caricina* Schroet.

Phyllosticta livida Ell. & Evht. On *Quercus macrocarpa,* Millston, Jackson Co. In these specimens the pycnidia are hypophyllous. If they really represent this species the fungus has a wide distribution in the U. S. previous collections being reported from California and Florida.

PHYLLOSTICTA LIATRIDIS n. sp. Spots round, white or sordid, arid, 1–2 mm. in diameter, usually surrounded by a broad black border; pycnidia epiphyllous, prominent, black, about 65μ; sporules hyaline, oblong, 2–4 nucleolate, about 10x4μ. On *Liatris spicata,* Gaslyn, Burnett Co. Aug. 1, 1911. This can hardly be *Phoma minutissima* Cke. as that species is described.

DIPLODIA UVULARIAE n. sp. Spots oval to orbicular, white, thin and arid, usually with a ferruginous border, 8-15x5–10mm.; pycnidia mostly epiphyllous, scattered, black, globose, 100–150μ; sporules elliptical to ovate, brown, uniseptate, 12–20x6–7μ. On *Uvularia (Oakesia) sessilifolia* Spooner, Aug. 15, 1911 (type) and Gaslyn. What is probably imperfect material of this species has been collected at Blue Mounds on *Uvularia grandiflora.* It is not unlikely that *North Am. Fungi* 2153 issued under the *nomen nudum Phyllosticta uvulariae* Galloway is of this character. (See 4th suppl. list under No. 359.) Macroscopically this fungus suggests *Phyllosticta cruenta* (Fr.) Kx. Occasional biseptate sporules occur as is to be expected.

Stagonospora intermixta (Cke.) Sacc. Price Co., Oct. 9, 1911. On leaves of *Cinna arundinacea.* I have not seen an authentic specimen of this species. The specimens which I have referred here have depressed-globose pycnidia 40–60μ in diameter with a round apical pore which is surrounded by a thick black ring. The long-fusoid sporules are 7—septate, 40–60x $3\frac{1}{2}$–5μ.

SEPTORIA ANDROPOGONIS, n. sp. Causing narrow elongated areas of a reddish-yellow color sometimes becoming sordid; pycnidia epiphyllous, subseriate or scattered, dark brown, depressed globose, little prominent, 75–100μ; sporules hyaline, straight or slightly curved, more acute at one end, becoming 2–4 septate, 30–50x2–3μ. On leaves of *Andropogon furcatus*, Gaslyn, Burnett Co. July 31, 1911.

SEPTORIA POLITA n. sp. Pycnidia scattered, globose, innate, black, ostiolate, 65–100μ; sporules hyaline, straight or somewhat curved, truncate to obtusely rounded at each end, becoming 3–5 septate, 35–50x$2\frac{1}{2}$–3μ. On *Carex sp. indet. (stellulata?)* Gaslyn, Wisconsin, Aug. 4, 1911. This attacks the distal portion of the very narrow leaves of the host which becomes sere. The sporules have a very smooth or polished appearance and are not at all constricted at the septa.

SEPTORIA CARPINEA (Schw.?) n. comb. Spots subcircular to angular, numerous, reddish brown becoming sordid in the center, somewhat paler below, 1–5 mm. in diameter; pycnidia epiphyllous, few, scattered, prominent, black, globose, ostiolate, about 65μ; sporules hyaline, usually curved, frequently arcuate, pluriguttulate, 25–40x2–3μ. On *Carpinus caroliniana*, Gaslyn, Wisconsin, Aug. 8, 1911. It seems quite possible that this is the fungus called *Xyloma* by Schweinitz and *Depazea* by Fries.

Septoria Polymniae Ell. & Evht. The specimens on *Polymnia canadensis*, collected near Somers in 1903, which I hesitatingly refer to this species show suborbicular spots $\frac{1}{2}$–1 cm. in diameter which become brown above, darker toward the margin. The pycnidia correspond with those of this species. My notes of the size of the sporules read 40–45x$1\frac{1}{2}$–2μ.

SACIDIUM MICROSPERMUM (Pk.) n. comb. *(Septoria microsperma* Pk.) On fallen leaf of *Betula alba papyrifera*. Butternut, Oct. 8, 1911. Hypophyllous on indefinite brown areas which show a tendency to extend along the veins; basidia and sporules in a discoid layer 100–150μ broad which is covered by a chitinoid, punctulate clypeus which becomes irregularly fissured; sporules straight or allantoid, 6–10 x ¾–1½μ. *North American Fungi* 674 on *Betula lenta,* collected by Nuttall in West Virginia, shows faded leaves with circular green areas. The pycnidia, however, are by no means confined to the green spots. In the West Virginia specimens also the sporules are smaller than in the type as described. I assume that it represents it in its *Sacidium* structure. Perhaps this is not distinct from *Leptothyrium betulae* Fckl.

(This has since been collected on the same host at Wausaukee.)

A *Gloeosporium* which has appeared in the greenhouse of the botanical department at Madison on the leaves of ***Dendrobium moschatum*** causes orbicular arid spots about 1 cm. in diameter with a dark purple border and elevated margin. The acervuli are brown, scattered, mostly epiphyllous; the sporules oblong to ovate-oblong, obtuse at both ends, biguttulate, 10–15x4μ. Probably this is *Gloeosporium cinctum* B. & C. and perhaps also *Gl. pallidum* Karst. & Har. The studies of Shear and Wood, however indicate that it is a conidial condition of *Glomerella cingulata* (Stonem.) S. & V. S. (U. S. Dept. of Agr., B. P. I., Bull. 252).

Colletotrichum helianthi n. sp. Spots definite, orbicular, olivaceous with a cinereous center and a black margin, paler below, often confluent, 3–5 mm. in diameter; acervuli very prominent, one or few on a spot, 50–65μ broad, surrounded by black rigid bristles 80–150x3–5μ which taper from base to apex; sporules hyaline, fusiform to arcuate, nucleolate, acute at each end, 25–35x2½–3½μ. On *Helianthus sp. indet.* Madison, Wisconsin, July 7, 1907. This is allied to *C. solitarium* Ell. & Barth. from which it differs in the larger bristles and sporules. I found the specimen in the herbarium of the University of Wisconsin with the name of the collector not given

Ovularia asperifolii Sacc., var. lappulae n. var. Spots suborbicular, dark brown, ½–1 cm; conidiophores hypophyllous, scattered or in tufts of 2–4, hyaline, often toothed, usually 16–20x3–4μ; conidia in chains which are sometimes branched, hyaline, 6–18x3–4μ; the lower conidia are cylindrical, acute at each end, 12–18x3–3½μ, the upper fusoid, 6–12x3–3½μ. Much longer hyphae (*ca.* 50μ) have been observed bearing conidia singly and laterally. On *Lappula virginiana.* Somers, Racine and Blue Mounds. While this fungus causes conspicuous spotting of the leaves the conidia are inconspicuous and evanescent. I have had it under observation for a number of years expecting at some time to secure specimens with a more profuse development of conidia. A specimen collected at Blue Mounds, July 13, 1912, is taken as the type. A more recent collection made at Potosi bears conidia up to 30μ in length. The Wisconsin fungus seems to be closely allied to var. *symphyti-tuberosi,* Allesch. (*Hedwigia,* 1894, p. 73.) These specimens differ from *Hermodendron farinosum* Bon. as figured (Bot. Zeit., t. VIII, fig. 9) in the longer and narrower conidia and the absence of the two guttulae in the lower members of the chain.

During August and September, 1912, there was collected at Madison on leaves of *Ribes americanum* a fungus of which the following notes were made: ''Spots angular, limited by the veinlets, often confluent into irregular areas, brown, 2–5 mm. in diameter; conidiophores hypophyllous in scattered tufts, closely fasciculate from a prominent sclerotioid base, hyaline, often toothed, 30–65x2–3μ; conidia terminal and lateral, hyaline, cylindrical, abruptly acute or rounded at each end, occasionally with a median septum, 20–50x3–4μ. The tufts usually have more or less of a pink tinge. Large fasciculi have a marked stilboid appearance.'' Leaves bearing the fungus were wintered out of doors and the following May were found to bear heads of conidia up to 250μ or more in diameter of a vinous purple color with the conidiophores compacted into blackish stipes *usque* 150μ high each springing from the summit of a plectenchymatous pseudopycnidium. The conidia borne on these heads were hyaline, catenulate, fusoid, continuous, 10–18x3–4μ. With these were fasciculi, snow white to purplish, of the mucedine type and occasional broader ones more tubercularioid in appearance.

Accepting the coremium structure as the climax development of this fungus I have labeled the specimens GRAPHIOTHECIUM VINOSUM n. sp. and as it appears to be at least a facultative parasite have given it a place in this list.

Ramularia calthae Lindr. Specimens having the following characters have been referred to this species. Spots small, angular, immarginate, limited by the veinlets, becoming confluent, brown, more abundant near the margin of the leaf; conidiophores epiphyllous, tufted from a stromatoid base, erect, simple, hyaline, 15–30x1½–2μ; conidia similar, sometimes catenulate 12–24x1–1½μ. On *Caltha palustris.* Gaslyn, Burnett Co., Aug. 30, 1911.

CERCOSPORELLA EXILIS n. sp. Spots round to angular, limited by the veinlets, often confluent, brown, 2–5 mm.; conidiophores in small loose tufts which are effused over the lower surface of the spots, hyaline, continuous, usually subulate, nearly straight, seldom branched, 10–20x2½–3½μ; conidia cylindrical, straight, hyaline, continuous or obscurely septate, 20–40x1–2μ. On *Phryma Leptostachya.* Madison, Blue Mounds and Devils Lake, August and September.

Cladosporium paeoniae Pass. On *Paeonia* (cult.) Madison. Pending an investigation of the diseases of paeonies in the United States, which I am informed,is to be made, I use this name provisionally.

Cladosporium gloeosporioides Atk. On *Hypericum virginicum.* Grand Rapids (Peltier) and Madison. This forms definite alutaceous spots on the leaves. When, however, the host plants are in a thick overshadowing growth of *Carices* and other taller plants the hyphae are borne on indefinite discolored areas. Frequently all gradations may be seen on a single host; on the upper leaves, exposed to the sunlight, the hyphae being confined to definite tan colored spots while on the lower they are borne on indefinite subolivaceous areas. I find the length of the hyphae variable; in some specimens 20–30μ, in others *ca.* 60μ. Dr. R. A. Harper has kindly compared this with specimens of ***Gloeosporium cladosporioides*** Ell. & Hals. in the Ellis Herbarium and transcribed the following notes from the inside of one of the envelopes; "Hyphae 35–40x4μ, fasciculate, nodulose above, hyaline becoming dark; conidia oblong-elliptical 10–14x4–6 microns". Dr. Harper writes:

"The spores seem like those on your material but the fungus on Halsted's material seems to be almost if not entirely on the stem. His host plant, of course, has narrow leaves quite different from yours. I did not get a good preparation of the conidiophores; I should think the two might be the same but I am doubtful. The New Jersey fungus is certainly not as conspicuous as yours and produces no such leaf spots.''

Considering the differences in the hosts it seems to me that there is a variable *Cladosporium* on *Hypericum* to forms of which these two names were applied. If that is the case I would prefer the later name here used to avoid tautology.

CERCOSPORA FINGENS n. sp. Spots suborbicular, immarginate, blackish brown, 3–5 mm.; conidiophores hypophyllous, olivaceous brown, somewhat crooked, denticulate, thicker and paler toward the apex, pluriseptate, 130–250x4–6μ; conidia hyaline, pluriseptate with a tendency to break apart at the septa, somewhat flaccid, tapering upward, 100–215x3–5μ. On *Thalictrum dasycarpum,* Burnett, Washburn and Price Counties, July–September. On *Thalictrum dioicum,* Lone Rock, (R. A. Harper and G. M. Reed). Because of the long and slender hyphae and conidia this resembles, under a hand lens, *Phytophthora thalictri* Wils. & Davis for which it was mistaken in the field.

I was at first disposed to refer this to *Cercospora aquilegiae* Kell. & Sw. but as no specimens have been collected on *Aquilegia* in Wisconsin, I infer that it is distinct.

Puccinia microsora Koern. Amphi-and teleuto-spores on *Carex Tuckermani* Price County and *Carex scabrata,* Bayfield.

Coleosporium sonchi-arvensis (Pers.) Lev. II, III, on *Sonchus asper,* I on *Pinus sylvestris,* Sturgeon Bay. The uredinia were collected by Mr. J. G. Sanders, Entomologist of the Wisconsin Agricultural Experiment Station, who found it to be locally abundant. The aecia usually appear upon but one of the paired leaves.

Herbarium of the University of Wisconsin, Madison Wisconsin, March, 1913.

NOTES ON PARASITIC FUNGI IN WISCONSIN—II.

J. J. Davis.

This communication holds a supplementary relation to *A provisional List of parasitic Fungi in Wisconsin* which was presented to the Wisconsin Academy of Sciences, Arts and Letters in March, 1912, and published in its Transactions, volume XVII pt. 2. After some notes of a miscellaneous character a list is given of hosts and another of species additional to those previously reported for Wisconsin. A communication of similar scope was presented to the Academy in April, 1913, and is published herewith.

University of Wisconsin Herbarium, Madison, Wisconsin, April, 1914.

Peronospora viciae (Berk.) D. By. In the provisional list a question mark was placed after *Vicia americana* where given as a host of this mildew. The reason for this is that the conidia of the downy mildew collected on this host in Wisconsin are longer than those of *P. viciae* on *Pisum* or on foreign species of *Vicia* as far as I have examined them. All of the specimens on native species of *Vicia* I have seen are similar to those that have been collected on *V. americana* in Wisconsin. The Wisconsin station is near Lake Mills and on the railroad right of way where the mildew may have been introduced from the plains region which seems to be the habitat of this form. Such evidence as I have seen indicates that the American and European forms are physiologically distinct. I would suggest that the native form be distinguished as *Peronospora viciae* var. *americana*—with conidia 30(24–36) x 20(17–26) and that *Fungi Columbiana 1836* on *Vicia linearis* Stockton, Kansas, Bartholomew, be taken as the type of this variety.

An interrogation point was also placed after *Acalypha virginica* where given as a host of *Peronospora euphorbiae* Fckl. in the provisional list because the quantity collected was insufficient for determination. Further search has been fruitless save for one conidiophore.

Plasmopara ribicola Schroet. The young oöspores of this species that I have seen are few, scattered, globular, smooth, 26–33μ in diameter. The oögonial wall is often symmetrically thickened on two opposite sides.

Protomyces fuscus Pk. appears to be a race of *Plasmopara pygmaea* (Ung.) Schroet. that produces oöspores abundantly but conidia not at all. I have had this form under observation for a number of years with reference to the appearance of conidia. The similarity of the spores to the oöspores of *Plasmopara pygmaea* (Ung.) Schroet. and the presence of antheridia indicate the character of the fungus. I label it *Plasmopara pygmaea* var. *fusca* (Pk.) although it loses the character of the genus with the suppression of conidia.

Protomyces andinus Pat. In 1911 this was collected at Butternut and Madison on *Bidens* with but few scattered resting spores and no hypertrophy of the host. Examination of fixed material of this kind showed the nuclei to be degenerating. I have not seen it on *Bidens* since although abundant on *Ambrosia.*

Septoria alnifolia Ell. & Evht. A hypophyllus *Septoria* on *Alnus incana* collected at Madison is probably of this species but doubtfully distinct from *S. alni* Sacc.

Septoria dentariae Pk. It is probable that this may properly be referred to *S. sisymbrii* Ellis as was done in the preliminary list. There is no question, however, as to its being the fungus that was later described by Peck under this name. Hennings & Ranojevic have proposed the name *Septoria sisymbrii* for a Servian fungus (Ann. Mycol. *10*:390 (1910) which is perhaps not distinct from the American plant, but I have not seen Kab. & Bub. *Fungi Imp. Exs. 557.*

Gloeosporium saccharinum Ell. & Evht. (Proc. Acad. Nat. Sci. Phila. 1891, pp. 82–83) appears to have been founded upon material of an unusual character in which the fungus had run riot. The form ordinarily seen shows spots of subcircular outline 5–15 mm. in diameter. They are at first pale-olivaceous or reddish brown, become alutaceous, fading with age, the peripheral portion darker. They are sometimes confluent. The tissue of the spots finally disintegrates, becomes ragged and falls away centrifugally. The acervuli appear centrifugally, are epiphyllous, saucer shaped, 80–160μ in diameter, sometimes confluent.

Juniperus communis depressa was given as a host of *Cercospora sequoiae juniperi* Ell. & Evht. in the 4th supplementary list but was omitted from the provisional list. Additional specimens have been collected at Lake Mills by E. M. Gilbert and the writer.

Puccinia cirsii-lanceolati Schroet. I find in the herbarium aecia of this rust collected at Blue Mounds.

Puccinia rubigo–vera (D C.) Wint. *Secale cereale* seems to have been omitted from the list of hosts of this rust in the provisional list.

Gymnosporangium clavariaeforme (Jacq.) D C. Telia have been collected on *Juniperus communis depressa* at Merrimack and Sullivan. They were abundant at the latter station.

Phragmidium occidentale Arth. In the provisional list aecia and telia were reported. Uredinia have since been collected at Ellison Bay in the northeastern corner of the state. Previous collections were made in the northwestern portion.

Melampsoropsis ledicola (Pk.) Arth. Telia of this species were collected at the same time as those of the following. The uredinia have not yet been collected in Wisconsin. The record "I" in the provisional list was founded on a single collection of *Peridermium decolorans* Pk. in Vilas county.

Melampsoropsis ledi (Lk.) Arth. Germinating telia were collected at Sturgeon Bay June 24th, 1913.

Melampsoropsis chiogenis (Diet.) Arth. In *N. A. Flora* the type locality of this rust is given as "Forest City" which should read Forest county. The station is now included in Oneida county.

Pucciniastrum myrtilli (Schum.) Arth. Specimens bearing telia were collected at Athelstane. The teliospores were more abundant in the epidermal cells of the upper surface of the leaves. Fraser (*Mycologia 5*:237, 6:27) finds that the aecia are borne on the leaves of *Tsuga canandensis.* The *Peridermium peckii* of the provisional list probably belongs to this species.

The *Aecidium sp. indet.* on *Amphicarpa monoica* of the provisional list is *Aecidium falcatae* Arth.

Senecio aureus was unintentionally omitted from the enumeration of hosts of "*Aecidium compositarum*" in the provisional list. Collections of aecia on this host have been made at Racine, Radisson and Merrimack.

According to the inoculation experiments of Fraser (*Mycologia 4*:236, *6*:25) the *Peridermium balsameum* Pk. of the provisional list is probably the aecial stage of *Uredinopsis.* There seems to be no way at present of determining with which of the five described species of *Uredinopsis* that occur in Wisconsin any particular specimen of the *Peridermium* is connected. Fraser has found that *Calyptospora goeppertiana* Kuehn also produces a *Peridermium* on *Abies balsamea.* This rust probably occurs also in Wisconsin but has not yet been collected.

Caeoma abietis-canadensis Farl. has been shown by Fraser (*Mycologia 3*:188, *5*:238, *6*:27) to be the aecial form of a *Melampsora* on *Populus grandidentata* which does not produce aecia on *Larix.* Probably some, if not all, of the uredinia and telia collected in Wisconsin on this host are of this race.

Entyloma lineatum (Cke.) Davis. Material that had been wintered out of doors was brought to germination in tap water slide cultures early in May. The normal germination appears to be in the sorus, isolated spores seldom germinating. The promycelium is consequently long (usually 35–50μ) and is flexuose and irregularly nodulose, reminding one of the conidiophores of *Ramularia.* The sporidia are borne in apical whorls of 2 to 4, are fusoid—cylindrical, 7–14x2μ. The whorl of sporidia is detached intact together with about an equal length of the distal portion of the promycelium and then rises to the surface of the water in the currents of which it revolves and moves in a very irregular manner. This is the same method of detachment that takes place in *Entyloma nymphaeae* (Cunn.) Setch. (Trans. Wis. Acad. Sci. Arts & Letters *11*:176) and is probably correlated with the aquatic habit. It seems to be of service in increasing the flotation of the sporidia and the likelihood of their catching upon the host. That this method of detachment is not constant, however, is indicated by the fact that Setchell does not mention it in his account of the germination of the spores of this species but refers to the sporidia as falling from the promycelia. (*Bot. Gaz.* *19*:188 [1894].)

Additional Hosts.

Not previously recorded as bearing the fungi mentioned in Wisconsin.

Peronospora parasitica (Pers.) Tul.—On *Arabis hirsuta.* Fish Creek.

Synchytrium aureum Schroet. A few galls on *Caltha palustris* apparently caused by this fungus were collected at Wausaukee in August, 1913, but the material is scanty and immature.

Plasmopara pygmaea (Ung.) Schroet. Conidia and oospores on *Hepatica triloba.* Afton.

Peronospora grisea Ung. On *Veronica americana.* Ellison Bay.

Sphaerotheca mors-uvae (Schw.) B. &. C. on *Ribes gracile.* Detroit Harbor.

Microsphaera alni (Wallr.) Wint. On *Alnus incana.* Wausaukee. Perithecia sparse.

Dimerosporium collinsii (Schw.) Thuem. On *Amelanchier, oblongifolia.* Merrimack, May 3rd, 1913. (W. N. Steil). On leaf of preceding year but ascospores not yet formed.

Exoascus confusus Atk. On fruit of *Prunus virginiana.* Sturgeon Bay.

Exoascus insititiae Sadeb. On *Prunus pennsylvanica.* Sturgeon Bay, causing witches brooms.

Exoascus cerasi (Fckl.) Sacc. On *Prunus Cerasus* (cult.) Wyalusing.

Exoascus coerulescens (Mont. & Desm.) Tul. On *Quercus coccinea.* Richland Center. (R. A. Harper & G. M. Reed.)

Taphrina virginica Seym. & Sadeb. On *Ostrya virginiana.* Potosi.

I am indebted to Mr. H. G. MacMillan of the Wisconsin Agricultural Experiment Station for identification of specimens in this group.

Stagonospora intermixta (Cke.) Sacc. To this species I have referred specimens of which the following notes were made. On elongated light brown dead areas which soon spread over the whole leaf; pycnidia epiphyllous, scattered, dark brown, globose or depressed-globose, 60–100μ in diameter; sporules at first hyaline and cylindrical becoming acute at one end with a central row of small guttulae, finally septate and tinted, 26–52x3–4μ. On *Phalaris arundinacea.* Devils Lake, Wisconsin, August 5th, 1913. The pycnidial wall is usually thin at the base while the outer portion is thick and blackened.

Septoria agrimoniae-eupatorii Bomm. & Rouss. On *Agrimonia gryposepala.* Potosi and Glen Haven.

Septoria cacaliae Ell. & Kell. On *Cacalia atriplicifolia.* Lake Mills. Oct. 26, 1901.

Septoria silphii Ell. & Evht. On *Heliopsis scabra.* Madison. Sporules 26–36 x 1μ. This species was described as having sporules 35–50 x 1μ, but in specimens on *Silphium perfoliatum* collected at Madison they are but 26–36 x 1μ. The spots tend to become white and arid with age.

Entomosporium maculatum Lev. var. *cydoniae* Sacc. On *Pyrus Aucuparia.* Devils Lake. Sporules 20(16–23) x 8(6–10)μ.

Gloeosporium septorioides Sacc. On *Quercus rubra.* Devils Lake. In these specimens the sporules have a narrow median division of the cytoplasm which is sometimes apparent without staining.

Gloeosporium robergei Desm. On *Ostrya virginiana.* Somers, South Milwaukee and Devils Lake. In all the specimens which I have collected on this host the cuticle on the upper surface of the spots is rugose forming white dendritic lines. It is labeled var. *dendriticum* in our herbaria.

Gloeosporium ribis (Lib.) Mont. & Desm. On *Ribes Cynosbati.* Devil's Lake.

Marssonina martini (S. & E.) Magn. On *Quercus Muhlenbergii.* Bridgeport. Some of the leaves bear also larger paler spots *usque* 2 cm. in diameter with numerous acervuli resembling those of *Gloeosporium nervisequum* (Fckl.) Sacc. (*Gloeosporium canadense* E. & E.) but the sporules are uniseptate.

Cylindrosporium glyceriae Ell. & Evht. On *Glyceria canadensis.* Athelstane. The collection on this host bears longer sporules, an occasional one much longer, than the type.

Cylindrosporium betulae Davis. On *Betula alba papyrifera.* Wausaukee. Sporules *usque* 55 x 3μ. Microconidia are quite common in this species seeming to be produced especially when the stroma is erumpent and naked.

Microstroma juglandis (Bereng.) Sacc. On *Carya glabra.* Potosi.

Septocylindrium ranunculi Pk. On *Ranunculus septentrionalis.* Madison.

Ramularia occidentalis Ell. & Kell. On *Rumex Britannica.* Madison and Athelstane.

Ramularia pratensis Sacc. On *Rumex Britannica.* Athelstane.

Ramularia desmodii Cke. On *Desmodium illinoense.* Bridgeport.

Ramularia effusa Pk. On *Vaccinium pennsylvanicum.* Wausaukee. On these specimens the conidia are borne on definite orbicular spots about 5 mm. in diameter which also bear numerous black immature pycnidia.

Ramularia veronicae Fckl. On *Veronica serpyllifolia.* Madison. This specimen bears conidia 12–18 x 3μ with a median division of the cytoplasm.

Ramularia asteris (Sacc.) Barth. On *Aster lateriflorus.* Devils Lake.

Fusicladium radiosum (Lib.) Lind. On *Populus balsamifera.* Sturgeon Bay. But a single collection has been made on this host.

Cercospora caricina Ell. & Dearn. On *Carex castanea* and *C. intumescens.* Wausaukee. On *Carex retrorsa.* Detroit Harbor and Athelstane. In the specimen from the latter locality the conidiophores are only 15–25μ long.

Cercospora rhoina Cke. & Ell. On *Rhus glabra.* Madison and Bridgeport.

Ustilago utriculosa (Nees) Tul. On *Polygonum lapathifolium.* Madison (W. N. Steil).

Uromyces halstedii de Toni. On *Leersia oryzoides.* Wisconsin river bottom opposite Bridgeport. The only previous collection of this rust in Wisconsin was a scanty one made by Dr. Arthur at the dells of the Wisconsin river in 1893 on *Leersia virginica.*

Uromyces scirpi Burr. *Scirpus validus* is given as a host of this rust in Wisconsin in *North American Flora.*

Uromyces junci-tenuis Syd. On *Juncus Dudleyi.* Uredinia and telia at Wausaukee.

Uromyces proeminens (D C.) Lev. Telia on *Euphorbia glyptosperma.* Wausaukee. This name is used instead of the later *Uromyces euphorbiae* Cke. & Pk. in the wide sense in which that name was used in the provisional list although it is also the name which is applied, in the narrow sense, to the particular race which occurs on this host species.

Uromyces hyperici-frondosi (Schw.) Arth. Uredinia and a few telia on *Hypericum Kalmianum.* Fish Creek.

Puccinia coronata Cda. Aecia on *Rhamnus lanceolata.* Glen Haven.

Puccinia andropogonis Schw. An *Aecidium* on *Linaria canadensis* in the herbarium of the University of Wisconsin which was collected at Mazomanie in June, 1908, is perhaps of this species.

Puccinia cyperi Arth. Uredinia and telia on *Cyperus Houghtonii.* Athelstane.

Puccinia patruelis Arth. Telia on *Carex pennsylvanica.* Madison (E. T. Bartholomew) *North American Uredinales, 651.*

Puccinia curtipes Howe. On *Tiarella cordifolia*. Devils Lake.

Phragmidium disciflorum (Tode) James. Uredinia and telia on *Rosa acicularis* at Ellison Bay are probably *Ph. rosae-acicularis* Liro if one accepts that as a distinct species.

Melampsoropsis cassandrae (Pk. & Cl.) Arth. Aecia (*Peridermium consimile* Arth. & Kern) on *Picea canadensis*. Wausaukee.

Uredinopsis atkinsonii Magn. A collection on *Cystopteris bulbifera* from the Wisconsin river bluff opposite Bridgeport I have referred to this species.

Additional Species.

Not previously reported as occurring in Wisconsin.

Plasmopara viburni Pk. On *Viburnum Opulus americanum*. Wausaukee and Athelstane. Conidia and oospores. Oospores subepidermal, oogonia globose, *usque* 48μ in diameter, wall often irregularly thickened; oospores globose, 24–37μ in diameter, wall 2–4μ thick, smooth or nearly so.

Asterina cupressina Cke. On *Juniperus communis depressa*. Fish Creek.

Ascochyta wisconsina n. sp. ad interim. Spots orbicular to elliptical, gray with a narrow black border and frequently zonate above, brown with a less definite margin below, 1–3 cm. long; pycnidia epiphyllous, scattered, brown, prominent, globose to sublenticular, 85–110μ in diameter; sporules ovoid to oblong, hyaline, 4–8 x $2\frac{1}{2}$–$3\frac{1}{2}\mu$. Some of the longer sporules have a median septum and it is probable that well matured specimens would show this to be an *Ascochyta*. The affected leaf tissue seems quite friable and apparently fragments and falls away piecemeal. On *Sambucus canadensis*. Devils Lake. August 7, 1913. On examining a specimen of *Septoria sambucina* Pk. collected at Racine it was found to bear also an *Ascochyta* with sporules 8–10 x $2\frac{1}{2}$–3μ. The pycnidia are epiphyllous on spots 1–2 cm. long which are sordid-arid with a purple border above, olivaceous below. I use this name for convenience until the relationship of the fungus to the various species that have been described on *Caprifoliaceae* is known.

Ascochyta caulicola Laubert (*Ascochyta lethalis* Ell. & Barth.) On living stems of *Melilotus alba*. Madison (A. H. Gilbert).

Stagonospora paludosa (Sacc. & Speg.) Sacc. On *Carex retrorsa*. Athelstane.

Septoria betulicola Pk. The common *Septoria* on *Betula* in Wisconsin, first manifests itself by the formation of small (1–2mm.) scattered, angular, intervenular, black brown spots which are lighter colored below. These spots become surrounded by an indefinite yellow discoloration which later becomes of a more or less reddish brown above and light brown or buff below. These run together into indefinite areas usually 1–2 cm. in diameter. On the lower surface of these areas the usually few and scattered pycnidia are borne. These are subepidermal, globose, thick-walled, about 100μ in diameter. The sporules are straight to strongly curved, spuriously pluriseptate, 40–60x$1\frac{1}{2}$–2μ. This is the form that is usually distributed under the name *Septoria betulicola* Pk. although *North American Fungi* 2nd series, *2166* which resembles it was issued as *Septoria betulae* (Lib.). Other specimens show smaller (*ca.* 5mm.) darker, more definitely limited areas which become cinereous above. *Septoria betulicola* apparently has not been reported in any of the Wisconsin lists. The characters of the sporules seem to ally this with *Septoria betulina* Pass. *Septoria betulae* (Lib.) West. was reported in the supplementary list 402a. The specimen upon which this record was based (Three Lakes, June 25th, 1892) bears circular light yellowish brown spots 1–2 mm. in diameter with a definite dark brown border. The pycnidia are epiphyllous but visible below, globose, thick-walled, about 80μ in diameter; the sporules straight or curved, triseptate, 30–40x2μ. *Fungi Columbiani 1586* on *Betula occidentalis*, collected in Oregon and issued as *Septoria betulicola* Pk. seems to differ from this only in the more irregular spots and the much paler and less distinct border.

Septoria alni Sacc. On *Alnus incana.* Wausaukee. Referred to this species because of the short sporules, the longest of which attain 40μ.

Septoria hepaticae Desm. On *Hepatica acutiloba.* Glen Haven. I have collected this but once when it occurred in connection with *Protomyces fuscus* Pk.

Septoria cassiaecola Kell. & Swingle. On foliage leaves of *Cassia chamaecrista.* Glen Haven. Amphigenous on intervenular areas of the leaflets which are not at first discolored but which become brown.

Septoria senecionis-aurei n. sp. ad interim. On irregular indefinite grey portions of large brown areas of the radical leaves. Pycnidia epiphyllous, scattered, brown black, spherical, with a distinct cellular wall, 55–65μ in diameter; sporules hyaline, straight, 16–26 x 1μ. On *Senecio aureus.* Devils Lake, September 1, 1913. I use this name for convenience until the relation of the fungus to previously described forms such as *Septoria senecionis-sylvatici* Syd. and S. *adenocauli* E. & E. becomes known.

Gloeosporium cylindrospermum (Bon.) Sacc. On *Alnus incana.* Madison.

Marssonina neilliae (Hark.) Magn. On *Physocarpus opulifolius.* Wausaukee. Macroscopically this resembles *Entomosporium. Marssonina coronaria* (Ell. & Davis) is similar and doubtless closely related.

Marssonina baptisiae (E. & E.) On *Baptisia leucantha.* Bridgeport. The globose acervuli are not subcuticular, as one might infer from the description, but subepidermal or innate. Sporules as long as 33μ were observed. Septation of the sporules seems doubtful.

Marssonina rhabdospora (E. & E.) Magn. A collection on leaves of *Populus grandidentata* made on the bank of the Wisconsin river opposite Bridgeport September 18, 1913, bears hypophyllous subcuticular acervuli which are applanate to hemispherical, 75–150μ in diameter. The affected leaf areas are first yellow, then brown, then indefinite sordid spots appear which become determinate, orbicular, arid, zonate, 3–5 mm.

in diameter with a narrow dark margin. In these spots the leaf parenchyma separates from the venules and probably falls away leaving the venular network. The zonate spots look much like the work of leaf miners, the dark lines suggesting burrows containing excreta. From the closely massed, erect, straight hyphae of the acervuli are abstricted hyaline filiform sporules 7–11 x 2μ. *Fungi Columbiani 1587* (on *Populus tremuloides, Newfield,* N. J. J. B. Ellis.) issued under the name *Septoria musiva* Pk. bears similar but somewhat larger spots (1–2 cm.) and sporules 18–30x2–3μ uniseptate. I am considering the Wisconsin collection to be a microconidial state of this which I refer to *Marssonina rhabdospora* E. & E.

Since this was written collections on *Populus grandidentata* have been made at Phlox and Neopit. The following notes were made from the latter: Spots circular, alutaceous shading outward into reddish brown and with a darker margin, the upper surface darker than the lower, 1–4 mm. in diameter, sometimes confluent; acervuli hypophyllous, usually few; sporules generally straight, uniseptate, 18–33 x 2–3μ. In the Phlox collection the spots are more numerous, rather more angular and more frequently confluent.

Cylindrosporium vermiforme n. sp. Spots amphigenous, subcircular to irregular, immarginate, brown, 5–15 mm. in diameter; acervuli epiphyllous, scattered, subcuticular, flat, 40–60μ in diameter; sporules, hyaline, vermiform, curved, sigmoid or flexuose, pluriseptate, 150–250x4–5μ. On leaves of *Alnus incana* Devils Lake, Wisconsin. The sporules suggest eel worms in appearance. Specimens in the herbarium of the University of Wisconsin collected at Devils Lake, August 15th, 1906, by R. A. Harper show many of the sporules provided with a rostrum, 10–42x1–1½μ, at the apex. A collection made in August, 1913, does not show the "rostrum" but one made September 1, 1913, showed some of the sporules so provided. Living sporules, germinating in water, in addition to the lateral germ tubes, put forth one from the apex so like the "rostrum" that I infer that the beak is a germ tube put forth while the sporule is still *in situ*. Some sporules bearing a beak put forth in water a second tube alongside the rostrum and similar to it. Because of the large, erumpent, fasciculate sporules this might be referred to *Hyphales.*

Ascochyta saniculae n. sp. On indefinite, discolored, more or less mottled areas which may include the entire leaf; pycnidia scattered, innate, globose to lenticular, thin walled, light reddish brown with a round apical pore surrounded by a dark ring, 100–170μ in diameter; sporules hyaline, cylindrical, usually straight, 4-guttulate, 20–30 x 4–6μ. On leaves of *Sanicula marilandica.* Grant County, Wisconsin, September 19th, 1913. The pycnidia are very inconspicuous. They are most readily seen by transmitted light when they show as translucent points.

Cylindrosporium shepherdiae Sacc. (*Ann. Mycol. 11*:551. 1913). To this species, founded upon material collected at Field, B. C. by Dearness, I am referring specimens from which the following notes were made. The spots are circular, reddish brown, concentrically rugose, 3–5 mm. in diameter. They have a greenish border and are seated upon an indefinite yellowish area. The epiphyllous pycnidia (?) are aggregated in the central portion of the spot, are soon erumpent, and widely open, the white mass of sporules within being visible under a hand lens. The sporules are hyaline, oblong-cylindrical, obtuse, pluriseptate, 18–40 x 3–4μ. Collected on *Shepherdia canadensis* at two stations near Ellison Bay and at Detroit Harbor. I have not seen *Septoria argyraeae* Sacc. which I suspect is not very different.

Ramularia fraxinea n. sp. Spots none, the fungus appearing as small snow white patches on the lower surface of the leaves; conidiophores densely clustered on a more or less hemispherical stroma, hyaline, sometimes bulbous at base, 10–20 x 3–4μ; conidia apical, hyaline, cylindrical, obtuse at both ends, distal ⅓–½ more or less strongly curved, becoming 1–4 septate, 40–80 x 4–5μ. On languishing leaves of *Fraxinus pennsylvanica.* Bridgeport, Wisconsin, September 17, 1913. The gross appearance suggests a light development of *Microstroma* and the shape of the conidia a hockey stick. Perhaps this should be referred to *Fusarium.* Since collected on *Fraxinus pennsylvanica lanceolata* at Maiden Rock.

Cercosporella nivea Ell. & Barth. On *Solidago uniligulata.* Athelstane. The specimen referred here bears conidia *usque* 118 x 3–4μ on short conidiophores. The affected leaf areas are not at first discolored but later become dead and brown and the air spaces contain hyaline mycelium and immature pycnidia or perithecia.

CERCOSPORA ECHINOCHLOAE, n. sp. Spots elongate-linear reddish brown, becoming arid in the center; conidiophores hypophyllous in small tufts, brownish tinted, continuous, straight or bent, entire or denticulate or oblique at the apex, 10–26 x 4μ; conidia, hyaline, straight or curved, cylindrical to obclavate-cylindrical, distinctly 1–7 septate, 23–53 x 3–4μ. On leaves of *Echinochloa Crus-galli.* Devils Lake, Wisconsin, August and September 1, 1913.

Cercospora passaloroides Wint. Poor specimens of this fungus on leaves of *Amorpha fruticosa* were collected on the bank of the Wisconsin river opposite Bridgeport. Better specimens have been collected at Trempealeau.

FUSARIUM CARPINEUM n. sp. Hypophyllous on indefinite areas which often follow the principal veins and which come to have a wilted appearance and finally assume a lethal brown below and almost black above; sporodochia superficial, convex to subhemispherical, 25–40μ in diameter, composed of globose cells 7–8μ in diameter which become flask shaped and 12–15μ long; conidia borne singly on the apex of these conidiophores, hyaline, cylindrical, obtuse at both ends, curved, biseptate, 35–50 x 3–4μ. On *Carpinus caroliniana,* Wyalusing, June 12, 1913.

Uromyces graminicola Burr. Telia on *Panicum virgatum.* Madison. On the railroad right of way. Perhaps adventive.

Puccinia melicae (Erikss.) Syd. Uredinia on *Melica striata.* Vilas county. Treboux states as the result of inoculation experiment that this is one of the forms of crown rust (*Ann. Mycol.* *12*:5:483 [1914]).

Puccinia gigantispora Bubak. Aecia and telia on *Anemone cylindrica* or *virginiana.* Glen Haven.

Puccinia cichorii (DC.) Bell. Uredinia and telia on *Cichorium Intybus.* Madison, (E. T. Bartholomew) *Fungi Columbiana 3933.*

Gymnosporangium corniculans Kern. Galls on *Juniperus horizontalis* on which were some dried teliospores agreeing with those of this species were collected on the lake Michigan beach east of Sturgeon Bay in June.

Hyalopsora aspidiotus Pk. Uredinia on *Phegopteris Dryopteris.* Detroit Harbor.

Melampsora farlowii (Arth.) n. comb. (*Necium farlowii* Arth.) On young twigs and leaves of *Tsuga canadensis.* Detroit Harbor.

Melampsora arctica Rostr. Aecia on leaves of *Abies balsamea* supposed to be of this species have been collected at Brule (E. M. Gilbert) Fish Creek and Ellison Bay. The reference to this species is based on the inoculation experiments of Fraser (*Mycologia* *4*:187, *5*:238). The uredina and telia have not yet been recognized in Wisconsin.

Aecidium xanthoxyli Pk. On *Zanthoxylum americanum.* Mazomanie (R. A. Harper & G. M. Reed) Glen Haven.

Aecidium proserpinacae B. & C. On *Proserpinaca palustris.* Detroit Harbor. Abundant on the marshy border of a pond on Washington Island.

INDEX TO HOSTS MENTIONED IN "NOTES" I AND II.

THE RELATION OF THE CORPUS CHRISTI PROCESSION TO THE CORPUS CHRISTI PLAY IN ENGLAND

MERLE PIERSON

INTRODUCTION

One of the theories concerning the rise of the vernacular drama in England traces the development of the Corpus Christi play from the Corpus Christi procession. The supposed evolution of the one from the other has been described by Mr. Davidson (*Studies in the English Mystery Plays,* p. 93) as follows:

> It seems, then, that shortly after the confirmation of Corpus Christi in 1318, pageants of the Biblical story were introduced in conjunction with the banners of the crafts. These at first were mute mysteries expressed by action. Indeed, connected pantomimic action would seem impossible in a moving procession; therefore this custom may be older than the spoken drama. In a short time, however, spoken drama, . . . became an established custom in England. A spoken drama necessitated frequent halts by the procession, as it was impossible to act satisfactorily in motion. These halts prolonged the procession beyond reasonable limit, and were avoided by transferring the pageants to the rear of the procession. A division of the procession immediately arose through the slower movement of the pageants, but the plays, though much belated, followed the traditional course of the procession through the city.

On the basis of this statement five stages in the development of the Corpus Christi pageant from the Corpus Christi procession might be assumed:

I. Crafts merely marching in the procession.
II. Crafts with banners in the procession.
III. Mute Mysteries.
VI. Spoken drama in the procession.
V. Separation of the plays from the procession.

On the authority of Mr. Spencer *(Corpus Christi Pageants in England,* p. 81) one more stage might be added:

VI. Pageant wagons and actors in the procession after the separation from the plays.

The evidence given by Mr. Davidson and by Mr. Spencer for each of these stages is, however, too meagre to be conclusive. It was in the hope of discovering additional material that I undertook this study.

To be definitive, the illustrations must show us the process as it worked out in some one place. It will not do to say that since in Durham, the crafts with banners marched in the Corpus Christi procession, since in France, the crafts acted mute mysteries, and since in Beverley the procession and the plays were separated, therefore the development followed the consecutive stages I, II, III, IV, V, VI. If, however, one should find that in Coventry every stage is represented in the correct order, he might assume that the theory was substantiated, at least for that one case. For each town, therefore, I have grouped together in a chronological order all the material on the Corpus Christi play and the Corpus Christi procession. Except in unimportant entries, the original language of the illustrations is given. In the first column to the left will be found the date to which the evidence refers; in the second narrow column, the authority (full titles are given in the bibliography). In the wide column at the left, is the evidence itself; in the wide right-hand column, a comment on the stage represented.

DOCUMENTS.

Aberdeen

Date	Document	Content	Interpretation
1440.	Davidson, p. 97.	"The play is mentioned in a regulation of 1440."	"It seems that on Corpus Christi day after the procession a play was usually performed on Windmill-hill. The play is mentioned in a regulation of 1440 and again in 1479, but it probably changed from year to year, and was under the care of the Abbot of Bonaccord. It certainly was not the charge of the gilds." Davidson, p. 97. Stage I.
1479.	Council Register, p. 410. See also Chambers, II, 331; Davidson, p. 97.	"The samyn dai, the consale and brethryn of gilde beand present for the tym, has consentit and ordanit the alderman to mak the expensis and costis—of the play to be plait in the fest of Corpus Xristi nixttocum."	

DOCUMENTS—Continued.

Aberdeen

Date	Document	Content	Interpretation
1512.	Register, p. 442.	"Every Craft—sall have a pair of torcheiss, —to decoir and worschip the sacrament one Corpus Xti day."	
1530.	Register, p. 449.	"The craftismen of this burgh sall, in thair best arraye, keep and decoir the processionis on XXi [Corpus Christi] day and Candelmas day ---every craft with thair avin banar, with the armes of their craft thairin, with thair pegane.—And every craft in the said processionis sall furneiss thair pegane and banar honestlie as effers, conforme to the auld statut maid in the yeir of God ja jvc tene yers."	'Pegane' probably refers to the pageant wagon for in the regulations for the Candlemas procession (1505/6) is this phrase "pageant that they furnyss to keip their geir." Chambers, II, 331. Stage VI, Stage II.
1531.	Register, p. 450.	"The Craftismen —keipe and decoir the procession on Corpus Christi dais, and Candilmes day—Every craft with thair Awin banar, with the armes of thair craft therein.—Every ane of the said craftis, in the Candilmes processioun, shall furneiss thair pageane, conforme to the auld statut, maid in the yeir of God jai vc and X yeris."	The furnishing of the pageants probably refers only to the Candelmas procession. Since by 1531, the Corpus Christi plays had been established, the carrying of the banners represents a survival from stage II, rather than stage II itself.
1533.	Chambers, II, 332	"'The craftismen—sall—keip and decoir, the processionis on XXi day and Candelmes day —every craft with thair avin banar—with their pegane.'"	
1538.	Council Register, p. 452.	Hammermen complain that "ameraris" usurp their place in Corpus Christi procession.	Stage I.
1546.	Chambers, II, 332	"Litsters ordered to 'haue thar banar and Pagane, as uther craftis of the said Burgh hes, ilk yeir, on Corpus Xhri day, and Candilmess dayis processiounis.'"	Stage VI, Stage II.
1553.	Register, p. 456.	Smiths convicted of "refusing Contempurindlie to gang in ordour in the processioun of Corpus Xris day."	Stage I.

DOCUMENTS—Continued.

Aberdeen

Date	Document	Content	Interpretation
1554.	Register, p. 457. See also Chambers, II, 332.	"Williame Robertsone, dekin of the smythis, comperit in judgement, —thai war in vse of ganging be thame selffis in the said processione, under thair awin baner, hindmaist and nixt the Sacrament, and the said wrychtis masouns, cowperis, and sklaiteris to proceid togidder befoir thame, under ane baner and pegane, separat fra the said smythis."	Stage VI, Stage II.
1556.	Chambers, II, 333	"Order for observance of statute as to Corpus Christi procession."	
	Davidson, note, p. 95.		"On Corpus Christi day the procession was under direction of the Abbot of Bon-Accord, later under that of Robin Hood."

Conclusion: Since by the first reference in 1440 spoken drama had already been established in Aberdeen, the succeeding references to the carrying of banners and the drawing of pageant wagons in the procession indicate merely a possible earlier connection between the procession and the plays. Certainly the gilds (contrary to Mr. Davidson's statement, p. 97) were concerned with both plays and procession (see entry 1479.) Because the pageant wagons were drawn in the procession, it is not necessary that the plays should have originated in it. The plays may have developed separately and have become attached to the Corpus Christi festival. The wagons might then have been sent in the procession to add to its splendor or to announce the plays. Obviously, material earlier than 1440, showing that the procession was flourishing before the first spoken drama, must be found to prove the validity of the theory.

DOCUMENTS.

Beverley.

Date	Document	Content	Interpretation
1377.	Hist. Mss., p. 65. Leach (2), p. 209. Chambers, II, 339. Bev. Town Doc., p. 45.	"Also, A. D. 1377, they agreed in the Guild hall that all tailors of Beverly should be present at the account of the expenses incurred by the pageant of the play of Corpus Christi."	Stage V.
1390.	Hist. Mss., p. 66. Chambers, II, 339. Leach (2), p. 208. Bev. Town Doc., p. 33.	38 specified crafts to "have their plays and pageants ('pagentes') prepared hereafter every day in the Feast of Corpus Christi, in manner and form according to the ancient custom of the town of Beverley."	Stage V.
1391.	Hist. Mss., p. 66. Leach (2), p. 209. Chambers, II, 339.	John of Erghes, hayrer, before 12 Keepers of town "undertook for himself and his fellows of the same craft to play a certain play called Paradise sufficiently, viz., every year on the feast of Corpus Christi when other craftsmen of the same town play, during the life of the said John of Erghes, at his own cost."	Stage V.
1392.	Hist. Mss., p. 66. Bev. Town Doc., p. 36. 2. Leach (2), 209.	1. Smiths pay penalty for not playing their play of Ascension on Corpus Christi day. 2. Play under penalty.	Stage V.
1409.	Hist. Mss., p. 89. Bev. Town Doc., p. 40.	"And the said goldsmiths shall yearly maintain—a torch in the procession on Corpus Christi day forever."	Stage I.
1410–11.	Hist. Mss., p. 97.	"Every master of the craft of coupers who shall newly occupy shall pay on his entrance to the use of the craft and costs of Corpus Christi play 2s.	Stage V.
1411(?).	Hist. Mss., p. 99.	Ordinances of Bowers and Fletchers under date of 1411 provide for play of "*Fleyng into Egip* and for play of *Habraham and Isaak*."	Crafts for play include trades not joined before 1416. (note in Hist. Mss., p. 99.)

DOCUMENTS—Continued.

Beverley.

Date	Document	Content	Interpretation
1411.	Hist. Mss., p. 67. Chambers, II, 341. Leach (2), 211. Bev. Town Doc., p. 34.	Those of the worthier sort, though they had not done so before, should on Corpus Christi day erect a pageant, and support it at their own cost, and cause a play to be played honourably and fittingly."	Stage V.
1413.	Hist. Mss., p. 98.	The Bowyers and Fletchers to "play or cause to be played, a certain pageant on Corpus Christi Day of Abraham and Isaac,' when the community on St. Mark's Day consent that the pageants generally shall be played.	Stage V. The procession seems to have been a settled yearly thing; it was necessary to vote on St. Mark's Day to have the plays.
1414.	1. Chambers, II, 339. 2. Leach (2), p. 211.	1. Barbers' ordinances require members to pay certain sums toward play. 2. According to ordinances of barbers, codified or written down in 1414, their play was the Baptism of Christ by St. John.	Stage V.
1416.	Hist. Mss., p. 101.	The tanners to "sus teyn and uphold forever —two torches of wax yerly and forever to be born in procession in the Feast of Corporis Christi."	Stage I.
1420.	Leach (2), p. 208.	According to ordinances of Carpenters' Gild the Resurrection was their play.	Stage V.
1423.	Hist. Mss., p. 160. Leach (2), p. 216.	Fines for neglecting pageants on Corpus Christi day.	Stage V.
1423.	Hist. Mss., p. 160. Leach (2), p. 214.	"Expenses of the Twelve Keepers on Corpus Christi day in governing all the pageants passing through the whole town."	Stage V.
1423.	Hist. Mss., p. 160. Chambers, II, 339.	"To Master Thomas Bynham, Frier Preacher, for making and composing the banns ('les banes') before the Corpus Christi play proclaimed through the whole town, 4 May, 6S. 8d. To the waits of the town, on the morrow of Ascension Day, riding with the said proclamation of Corpus Christi through the whole town, 20d."	Stage V.

DOCUMENTS—Continued.

Beverley.

Date	Document	Content	Interpretation
1423.	Leach (2), 216. Chambers, II, 340.	Roger Penycoke fined because he did not produce his pageant on Corpus Christi day. John, a "Cordewainer," fined for hindering divers pageants on Corpus Christi day.	Stage V.
1428.	Hist. Mss., p. 87.	"'The aforesaid Bakers and their successors shall forever find and maintain yearly on the day of the procession of Corpus Christi two torches of wax burning and to be borne before the most holy Body of Christ, under penalty of 6S. 8d.'"	Stage I.
1428.	Hist. Mss., p. 87. See also reference on p. 87 to the procession.	"'Moreover it is ordered that the brethern aforesaid (Bakers) shall play or cause to be played the pageant of Maundy as often as it shall be ordered to be played by the Governors of the town—.'" Certain regulations on support of pageant.	Stage V. Note, that the procession is maintained yearly; the play is given as often as ordered by the governor. This suggests that in 1428 there was no connection between the plays and the procession.
1430–1.	Hist. Mss., p. 68. Bev. Town Doc., p. 35. Chambers, II, 341.	"A dispute having arisen between the Aldermen and stewards of divers crafts on the carrying of their tapers or torches yearly before this time in the venerable procession of the feast of Corpus Christi, therefore—it was ordered—to be perpetually observed that in every year for the future on Corpus Christi Day the stewards of each craft underwritten shall pass with their lights in the said procession according to the form underwritten in their order."	This list of crafts in order is given at the end of the documents on Beverley. Stage I.
1430.	Chambers, II, 341.	Procession and play, though on the same day, seem to have been in 1430 quite distinct.	Stage V.
1436.	Hist. Mss., p. 68. Leach (2), 214.	"Every Alderman and Steward of any craft or rank should be prepared to play with their pageants on Corpus Christi Day 1437."	Stage V.

DOCUMENTS—Continued.

Beverley.

Date	Document	Content	Interpretation
1441.	Hist. Mss., p. 100.	Sadlers to play the pageant of the *Creation of the World* yearly on Corpus Christi day, whenever the 12 keepers of the town shall order plays.	Stage V.
1442.	Hist. Mss., p. 129.	"Rob. Peterer et Th. Cowton moniti sunt ad exponendum in gratiam communitatis xls; pro eo quod ipsi non habuerunt lumen suum artis Piscatorum in processione die Corpris Christi per festum ad Vincula Sancti Petri prox."	Stage V.
1446.	Hist. Mss., p. 131, 132.	" 'Uxor Egidii Bokeler, smyth', promised to pay 'solutio xld. annuatim Pistoribus quamdiu occupaverit, xxd. ad expensas castelli Pistorum et luminis, et ad expensas et costagia pagendae cum ludi contigerit xxd.' "	Stage V.
1449.	Hist. Mss., 133.	"Ordinatum est per decem de xij—quod pagendae ludi Corporis Christi assignentur in forma subscripta deludendae hoc anno: viz., ad Barras Borialis; juxta Bulryng; inter Johannem Skipwith et Robertum Couke in Alta Via; apud Crossebrig; apud Fisch-market: apud Mynstir bowe; et ad Torrentum.	Stage V.
1449.	Leach (2) p. 214. Chambers, II, 341.	Expenses of Governors, common clerk, and sergeant governing the pageants of the town on Corpus Christi through the whole day. "The play lasted only one day, and was given in 1449 at six stations." Chambers, II, 341.	Stage V.
1450.	Hist. Mss., 134. Leach (2), p. 216.	Certain fishers "moniti sunt hic ad exponendum [etc.] xls. quia non habuerunt pagendam suam deludendam die Corporis Christi hoc anno secundum consuetudinem villae—et transgressio pardonatur graciose sub hac condicione, quod praedicti Piscatores pagendam suam facient competenter in omnibus citra diem Dominicam in Ramis Palmarum proximum futuram post datam praesentium."	Stage V.

DOCUMENTS—Continued.

Beverley.

Date	Document	Content	Interpretation
1450.	Hist. Mss., 135.	Places for playing Corpus Christi play assigned. "In primis ad Barras Boriales. Item apud Bulryng. Item ad domum Johannis Skipwith. Item deinde apud Fischmarket. Item inter cer— (?) et campanam. Item ad monasterium. Item ad Torrentem."	Stage V.
1450.	Leach (2), p. 214.	Expenses of Twelve Governors governing pageants. Governors contribute to craft of Skinners for their play on Corpus Christi day.	Stage V.
1451.	Leach (2), p. 217.	Alderman of Skinners paid fine because he did not produce his play on Corpus Christi day.	Stage V.
1452.	Hist. Mss., p. 136.	"Porters and Crelers inferius nominati moniti sunt praedicto die et anno quod habeant j pagendam de novo factam ad ludendum super die Corporis Christi proximo futuro post datum praesentium seu festum annunc. B. M. V. prox. fut. sub poena forisfacturae xls. ad usum communitatis. Rob. Thornskew, aldermannus, monitus est hic xvj. die Jun. ad exponendum vjs. viijd. eo quod lusores artis carpentariorum nesciebant ludum suum die Corporis Christi contra poenam proclamationis communis campanatoris."	Stage V.
1452.	Chambers, II, 340 Leach (2), p. 216.	Fine on Henry Cowper for not knowing his part in play ("nesciebat ludum suum'") on Corpus Christi day.	Stage V.
1455.	Hist. Mss., p. 89.	"'Payntners, goldsmyths, masons and glasears.'—"To be one brotherhood 'and have yearly a pageant of Three Kings de Celane.'"	Stage V.
1456.	Leach (2), p. 216.	William Hoseham warned to put down 40s. "because the players of the pageant of the Dyers' craft were not ready to play their pageant in the first place at the North Bar."	Stage V.

DOCUMENTS—Continued.

Beverley.

Date	Document	Content	Interpretation
1457.	Hist. Mss., p. 68. Bev. Town Doc., p. 36.	"The common burgesses of the town of Beverley in their Gild Hall assembled petition the venerable keepers or governors of the said town to have their plays yearly on Corpus Christi day as they were accustomed to have."	Date given as 1456 in Leach (2), p. 214. Stage V.
1459.	Hist. Mss., p. 139 Leach (2), p. 217	"Thomas Law, Alderman artis carnificum Beverlaci, et alii confratres sui venerunt in Gildam Aulam Beverlaci praedicti, et xls. monetae Angliae in gratiam communitatis posuerunt pro eo quod cum lusoribus suis tarde venerunt ad portas Boriales. Beverlaci praedicti ad ludendum pagendam suam in festo Corporis Christi ultimo elapso."	Stage V.
1460. 1465.	Leach (2), p. 215. Chambers, II, 339 Hist. Mss., p. 96.	Twelve governors erect a scaffold for "'sitting at the North Bar to see and govern the pageants.'"	Stage V.
1465.	Hist. Mss., p. 96.	"Every contributor of the said craft [Smiths] shall pay his Alderman yearly when the Corpus Christi play is played 4 d. to the maintenance of the pageant, and every journeyman 2 d."	*"This article has 'Vacat' in an Elizabethan hand written against it."* Hist. Mss. ibid. Stage V.
1467.	Leach (2), p. 212.	Regulations for support of pageant.	Stage V.
1469.	Chambers, II, 339.	Same as above.	Stage V.
1469.	Chambers, II, 339.	Amounts paid by journeymen cappers towards support of pageant.	Stage V.
1475.	Hist. Mss., p. 102.	Cutlers, Braziers, and allied trades to have a torch in the Corpus Christi procession.	Stage I.
1475.	Hist. Mss., p. 102.	"Robert Rider, 'Braciar,' Alderman, and William Cardmaker and Robert Lovell, stewards of a certain pageant of the crucifixion of Christ accustomed to be played on Corpus Christi Day, because divers men of divers crafts who ought	Stage V.

DOCUMENTS—Continued.

Beverley.

Date	Document	Content	Interpretation
		to contribute to the playing and maintenance of the said pageant have refused and refuse, to do so; Therefore they made the ordinances — underwritten— First, that all cutlers, Furberors, Plumbers, Braziers, Cardmakers, and Pewterers (*written in a different hand* "and Pynners") in the liberty of Beverly there should be one Brotherhood, and that they and each of them should support the charge of the said pageant, and should perform and cause the same to be played for ever."	
1485.	Hist. Mss., p. 103.	f. 79 headed—"Their Play the 'Redemption of Adam and Eve, called le Coke Pageant.'"	Stage V.
1491.	Hist. Mss., p. 103.	Millers' Ordinances, 1491. "Pageant of the Resurrection of Lazarus."	Stage V.
1493.	Hist. Mss., p. 100.	"Every maker of 'lade sadyll panels' to pay to maintenance of play and light 8 d. a year."	Stage V.
1493.	Bev. Town Doc., p. 99, p. 101.	Drapers to play 'Dooming Pilate' whenever plays are given. Regulations on support of Corpus Christi play.	Stage V.
1493.	Chambers, II, 340.	The play of the Drapers and Mercers divided, Drapers taking 'Demyng Pylate' and Mercers 'Blak Herod.'	Stage V.
1494.	Hist. Mss., p. 101.	Journeymen to pay toward expenses of Corpus Christi play when it is played.	Stage V.
1498.	Hist. Mss., p. 68. Bev. Town Doc., p. 68.	"'Allso it is ordande by the forsayde xij Governors—that the forsayde xij for tyme beyng shall go yerly in processyon on Corpus Christi day, or on the morue after, as itt shall happen, afore all the aldermen; and evere man of the other two bynks [benches] to go with there alderman of ther occupacyon in thar clothyng belongyng to thar brodyrhed.'"	Stage I. Note that the day of the procession is variable. This suggests that there was no connection between the plays given on Corpus Christi day and the Corpus Christi procession.

DOCUMENTS—Continued.

Beverley.

Date	Document	Content	Interpretation
1519.	Hist. Mss., p. 171.	Expenses of the Governors "being with Sir William Pyers, poet *(sic)*, at Edmund Metcalff's house to make an agreement with him for transposing ("transposicione") the Corpus Christi Play."	Stage. V.
1520.	Hist. Mss., p. 172. Leach (2), p. 217. Chambers, II, 340.	Alderman of painters fined because his play of the Three Kings was badly played.	Stage V.
1520.	Hist. Mss., p. 172. Leach (2), p. 217.	Alderman of Tailors fined because his play of "Slepying Pilate" was badly played.	Stage V.
1520.	Hist. Mss., p. 173.	Expenses for 12 Governors at time of Corpus Christi play.	Stage V.
1555.	Chambers, II, 341.	Mr. Chambers finds mention of plays in 1555.	Stage V.

Mr. Davidson suggested that the "order of the Gilds is a matter of importance to us, as the earliest order of the gilds in the craft plays was doubtless the same as in the procession" (p. 91). I have arranged in tabular form the list of crafts (in order) in the processions for 1430 and 1498, and compared them with a list of crafts (in order) for the plays of 1520. The list of 1520 will serve for the hundred years between 1420 and 1520 since the same crafts seem to have given the same plays for the whole period.

1. The play of the Smiths in 1392 and in 1520 is the same.
2. The play of the Bowers in 1411 (?), 1413, and in 1520 is the same.
3. The play of the Barbers in 1414 and in 1520 is the same.
4. The play of the Carpenters in 1420 and in 1520 is the same.
5. The play of the Bakers in 1428 and in 1520 is the same.
6. The play of the Sadlers in 1441 and in 1520 is the same.
7. The play of the Goldsmiths (Painters, Masons, etc.) in 1455 and in 1520 is the same.
8. The play of the Cooks in 1485 and in 1520 is the same.
9. The play of the Millers in 1491 and in 1520 is the same.
10. The play of the Drapers in 1493 and in 1520 is the same.
11. The play of the Mercers in 1493 and in 1520 is the same.

Beverley.

DOCUMENTS—Continued.

Crafts that gave plays 1390.	Processions. 1430.	Processions. 1498.	Plays. 1520.
Mercers and Drapers.	Clergy of the Gild of Corpus Christi,	12 Governors.	Tylers: the fallinge of Lucifer.
Tannatores.	The Gild of the Blessed Mary.	Aldermen of the following:	Saddelers: the makinge of the World.
Masons.	The Gild of St. John of Beverley.	Merchants.	Walkers: makinge of Adam and Eve.
Skynners.	Merchants.	Drapers.	Ropers: the brekinge of the Comaundments.
Taillors.	Cloth Workers.	Bowchers.	Crelers: gravinge and Spynnynge.
Goldsmyths.	Butchers.	Baxters.	Glovers: Cayn.
Smyths.	Bakers.	Wryghts.	Sherman: Adam and Seth.
Plummers.	Carpenters.	Smyths.	Wattermen: Noe Shipp.
Bollers.	Smiths.	Taylors.	Bowers and Fletshers: Abraham and Isaak.
Turnors.	Tailors.	Tylers.	Musterdmakers and Chanlers: Salutation of our Lady.
Girdelers.	Skinners.	Shomakers.	Husbandmen: Bedleem.
Cutlers.	Tanners.	Lyttsters.	Vynteners: Sheipherds.
Latoners.	Weavers.	Barkers.	Goldsmyths: Kyngs of Colan.
Brochmakers.	Sheremen.	Wevers.	Fyshers: Symeon.
Horners.	Fullers.	Walkers.	Cowpers: fleyinge to Egippe.
Sponers.	Sailors.	Glovers.	Shomakers: children of Ysraell.
Ladilers.	Barbers.	Bowers.	Scryveners: Disputacion in the Temple.
Furbars.	Glovers.	Cowpers and Fletchers.	Barbours: Sent John Baptyste.
Websters.	Coopers.	Wattermen.	Laborers: the Pynnacle.
Walkers.	Fishers.	Potters.	Mylners: rasynge of Lazar.
Coverlidwevers.	Tilers.	Barbors.	Skynners: ierusalem.
Cartwrightes.	Gild of St. Elen.	Cappers and Hatters.	Bakers: the Mawndy.
Coupars.	Gild of Pater Noster.	Sadyllers.	Litsters: prainge at the Mownte.
Fletchers.	Gild of St. John Baptist.	From Hist Mss., p. 69.	Tailyours: Slepinge Pilate.
Bowers.	Gild of St. John in May.		Marchaunts (Mercers): Blak Herod.
Cordewaners.	Gild of St. Peter Melon.		Drapers: Demynge Pylate.
Baksters.	From Hist. Mss., p. 68.		Bocheours: Scorgyne.
Flesshewers.			Cutlers and Potters: the Stedynge.
Fysshers.			Wevers: the Stanginge.
Chaundelers.			Barkers: the Takinge of the Crose.
Barburs.			Cooks: Haryinge of hell.
Vynters.			Wrights: The Resurrection.
Sadilers.			Gentylmen: Castle of Emaut.
Rapers.			Smyths: Ascencion.
Hayrers.			Prestes: Coronacion of Our Lady.
Shipmen.			Marchaunts: Domesday.
Glovers.			From Chambers, II, 340, 341.
Workmen.			
From Chambers, II, 340.			
(Crafts not in order)			

Conclusion: The order of the gilds in the craft plays is not the same as in the procession. Moreover, only stages I and V are represented at Beverley. The length of the plays (see entry 1449) would preclude any connection with the procession. Therefore, the procession and the plays from 1377 on, seem to have been distinct.

DOCUMENTS.

Bungay.

Date	Document	Content	Interpretation
1514.	Chambers, II, 343. Collectanea (L'Estrange editor), p. 272. (original document in latter).	In 1514 certain persons " 'brake and threw down five pageants of the said inhabitants that is to saye, hevyn pagent, the pagent of all the world, Paradyse pagent, Bethelem pagent and helle pagent, the whyche wer ever wont tofore to be caryed abowt the seyd town upon the seyd daye in the honor of the blessyd Sacrement.' ".	"There were pageants also in the Corpus Christi processions at Bungay and at Bury St. Edmunds, but the notices are too fragmentary to permit of more than a conjecture as to whether they were accompanied by plays." Chambers, II, 162. In the absence of further material, I should assign this reference to Stage III.

Conclusion: The material is too fragmentary to be conclusive.

DOCUMENTS.

Bury St. Edmunds.

Date	Document	Content	Interpretation
1477.	Chambers, II, 343.	Certain fines are to go to " 'the sustentacione and mayntenaunce of the payent of the Ascencione of oure Lord God and of the yiftys of the Holy Gost, as yt hath be customed of olde tyme owte of mynde yeerly to be had to the wurschepe of God, amongge other payenttes in the processione in the feste of Corpus Xri.' "	Notice Chamber's comment under Bungay above. This may refer to the drawing of the pageant-wagons in the procession (Stage VI), to Stage III, or to the processional nature of the cycle.

Conclusion: The material for Bury St. Edmunds is too fragmentary to be conclusive.

DOCUMENTS.

Canterbury.

Date	Document	Content	Interpretation
1490.	Hist. Mss., IX, pt. 1, p. 174.	"before this tyme ther hath bene, by the most honourable and worshipfull the Cite of Canterbury — a play called *Corpus Xpi Play*—of late daies it hath bene left and laide apart.—Wherfore it is enacted—that from hensforth every craft—being not corporate for their non sufficience of their crafts, be associate to some crafte moste nedynge support, yf they will not labour to be corporate within them selfe.—And yf eny suche crafte—wille not make suit to the Burgemote for the reformacion of the premisses by the seide feste (of St. Michael next ensuing)" they shall pay a fine and be subject to punishment.	Stage V.
1525.	Archæologia Cantiana, XVII, 85.	"Item for a calues hede flaggis and thredde at Corpus Christi day for ryngaris—vijd."	This and the following citations refer to the procession as directed by a church.
1527.	Arc. Cant., XVII, 88.	Same as 1525.	
1545.	Arc. Cant., XVII, 107.	"Item for flaggis bred and drynke on Corpus Christi day—ijd."	
1546.	Arc. Cant., XVII, 109.	For "flaggis" on Corpus Christi day.	
1547–8.	Arc. Cant., XVII, 111.	Same as 1546.	

Conclusion: The references at Canterbury are too few to be conclusive.

DOCUMENTS.

Chester.

Date	Document	Content	Interpretation
1358.	Morris, p. 405.	Trades go in Corpus Christi procession with candles.	Stage I.
1462.	Chambers, II, 352. Morris, p. 316.	"Baker's charter refers to their 'play and light of Corpus Christi.'"	Stage V.
1471.	Morris, p. 316.	Half of certain fines of sadlers are to go to the support of pageant, light, and play on the Festival of Corpus Christi.	Stage V.
1520.	Morris, p. 316.	"'The Stuards of the Founders and Pewters agree with the Stewards of the Smiths to bere and draw the Whitson Playe and Corpus Christi light.'"	The play was probably transferred to Whitsuntide to avoid a clash with the procession.
1520.	Morris, p. 349.	Certain gilds to have Corpus Christi light.	Chambers, II, 353.
1544–?	Chambers, II, 350.	"'On Corpus Xpi day the Colliges and prestys bryng forth a play on the assentement of the Maire.'" "There will be a 'solempne procession' with the sacrament on Corpus Christi day from 'Saynt Maries on the Hill' to 'Saynt John's," together with 'a play sett forth by the clergye In honor of the fest.'"	Note that this is not a craft play.
?	Morris, p. 309. Pre-Reformation. Banns.	"Also maister maire of this Citie with all his bretheryn accordingly A solempne procession ordent hath he To be done to the best Appon the day of Corpus Christi; The blessed sacrament carried shall be And a play sett forth by the clergye In honor of the fest Many torches there may you see Marchaunts and craftys of this citie, By order passing in their degree. A goadly sight that day They come from Saynt Maries on the hill The Church of Saynt John untill And there the sacrament leve they will, The south [sooth] as I you say.'"	Note that this is not a craft play.

DOCUMENTS—Continued.

Chester

Date.	Document.	Content.	Interpretation.
14 Ed. IV.	Morris, p. 572.	Controversy between bowers, fletchers on one side and cowpars on the other "for the beryng lights in procession with thaire lights on Corpus Day."	Stage I.

Conclusion: The data of composition of the Chester plays, originally given on Corpus Christi Day, is about 1327- (See Chambers, Vol. 2). The earliest reference to the Corpus Christi procession in England is at Ipswich in 1325 (Chambers II, 371). Clement V. at the Council of Vienne (1311) confirmed the bull of Pope Urban IV (1264) concerning the festival (Friedburg, Vol. II, Col. 1174–1177). By 1318, the feast was celebrated in almost every church in France. The feast was enjoined on Canterbury in 1332. The Exeter Ordinale speaks of Corpus Christi as a novelty in 1337. Therefore, it seems reasonable to suppose that the procession was not instituted in Chester much before 1325. If the date of the plays is + 1327, the development from procession to play (if there was one) must have been very rapid. Moreover, the Chester Whitsun plays took three consecutive days. The plays on Corpus Christi day could not have been much shorter, and therefore could not have been given during the procession. Plays and procession at Chester, though given on the same day, seem to have had no connection.

DOCUMENTS.

Coventry.

Date.	Document.	Content.	Interpretation.
1348.	Davidson, p. 93. Hist. Mss., XV, pt. 10, p. 113.	Guild of Corpus Christi founded. It was to carry torches about the sacrament.	The crafts apparently were not concerned in the procession at first.
1381.	T. Smith, English Gilds, p. 232, 233.	*Inspeximus* charter of 1381 confirms a license of mortmain granted to gild in 1348. A cross, a spear, and four banners are specified for procession on Corpus Christi day.	
1392.	Chambers, II, 357.	"'Domum pro le pagent pannarum'" mentioned in 1392.	Stage V.
1414.	Sharp, *Diss.*, p. 78.	The "Pynners and Nedelers" agreed to bear the charges and reparations of 'her pagent callyd the takyng down of God fro þe cros for ev'more amongs hem'—[and] "that they shall be clothed in one livery against Corpus Christi day,—and ride on that day with the Mayor and Bailiffs."	Stage V. Stage I. I take the second part of this quotation to refer to the procession.
1416. 1424.	Harris, p. 288. **Abbotsford, p. 19n.**	Henry V saw shows. Journeymen to contribute to the play.	Chambers, II, 357 questions date. Miss Harris insists that Sharp and Annals are incorrect on dates.
1428.	Sharp, *Diss.*, p. 8. See also Harris, p. 292. Poole, p. 39.	Smiths ask to be released from the cutlers' pageant which they were discharged of in 1414 and which they took up at request of Mayor in 1426.	Stage V.
1434.	Poole, p. 40. See also Sharp, *Diss.*, p. 9.	"Sadelers" and painters to contribute to the pageant of the "Cardemakers."	Stage V.
1435.	Sharp, *Diss.*, p. 79.	Carpenters ordered to associate with Tilers and Pinners in support of their pageant.	Stage V.
1444.	Leet Book, pps. 205, 206. Chambers, II, 360.	Men of certain crafts may not play in any other craft except by permission. Pageant of Cardmakers, saddlers, painters, and masons to be supported by the united fellowship.	Chambers, II, 360, Poole, p. 40, Sharp, *Diss.*, p. 81, date this entry 1443. Stage V.
1444.	Chambers, II, 362.	"The procession or 'Ridyng' on Corpus Christi day is first mentioned in the Leet Book in 1444."	Stage I.

DOCUMENTS—Continued.

Coventry.

Date	Document	Content	Interpretation
1444.	Sharp, p. 171.	Procession had been held time out of mind. Certain crafts to provide wax for the procession.	Stage I.
1445.	Leet Book, p. 220.	"Pur le Ridyng on Corpus *Christi* day and for Watche on Midsomer even. The furst craft, ffyshers and Cokes. Baxsters and Milners. Bochers, Whittawers and Glouers. Pynners, Tylers and Wrightes. Skynners. Barkers. Coruisers. Smythes. Weuers. Wirdrawers. Cardmakers, Sadelers, Peyntours and Mason[s]. Gurdelers. Taylours, Walkers and Sherman. Deysters, Drapers. Mercers."	Stage I.
1447.	Leet Book, p. 231.	Order that riding as from ancient times be kept up.	Stage I.
1448.	Sharp, *Diss.*, p. 163	Payment for bearing of torches on Corpus Christi day—Carpenters' Accounts.	Stage I.
1452.	Sharp, *Diss.*, p. 163.	Same as entry for 1448.	Stage I.
1452.	Sharp, *Diss.*, p. 79.	It was ordained that the "Wryghtes Crafte of Coventre schall paye to the Pageant X*s* upon Whytsonday or else by Corpus XPi daye uppon the payne of XXs halfe to the Meyor & halfe to the Crafte & they to have no more to doo wythe the Pageant but payeing there Xs."	
1453.	Chambers, II, 359. Original in Sharp, *Diss.*, p. 15.	Contract for the rule of the pageant.	
1454.	Sharp, *Diss.*, p. 163.	Same as entry for 1448.	
1457.	Leet Book, p. 300.	Queen came to see the plays.	1456 in Poole, p. 44.
1459.	Sharp, *Diss.*, p. 9.	Every craft that has a pageant shall make that pageant ready upon penalty.	Stage V.

DOCUMENTS—Continued.

Coventry.

Date	Document	Content	Interpretation
1459.	Sharp, *Diss.*, p. 160	From Trinity Guild accounts—"Exp's fact in festo Corpis XPi viz. ad iiijor Torchberers ad portend iiijor Tortices p tempus p cessional circa le Cowpe in quo continet Corp dñi."	
1461.	Sharp, *Diss.*, p. 79.	From Carpenters' Accounts—"payd to pynners & tylers for the page't.	Stage V.
1468.	Sharp, *Diss.*, p. 160.	"Itm to iiij torchberers in festo corp is XPi."	Stage I.
1469.	Sharp, *Diss.*, p. 21.	"It' for iiij Jaked men about the pagent."	Stage V.
1473.	Sharp, *Diss.*, p. 77.	"R' Joh'e Thrumpton & Thoma Colyns custodibz de m cers p reddit de pagent house."	Stage V.
1476.	Sharp, *Diss.*, p. 164.	"It ffor hors hyre to Herod." Smiths' Accounts.	Stage VI. It appears that the person who played the part "of Herod in the Smiths' pageant joined the Procession." Sharp, p. 164.
1476.	Sharp, *Diss.*, p. 164.	"'Hit is ordened at this p' sent leetą that ev'y Crafte wt in this Cite com wt their pageaunts accordyng as hit haith byn of olde tyme and to com wt their p' cessions & ridyngs also when the byn required by the Meir for the worship of the Cite in peyne of Xli.'"	The procession and the plays appear to have been separate in 1476.
1477.	Sharp, *Diss.*, p. 164.	Payment for bearing of torches on Corpus Christi day.	Stage I.
1481.	Sharp, *Diss.*, p. 15. Chambers, II, 359.	Contract for the rule of a pageant.	Stage V.
1485.	Harris, *Coventry*, p. 288.	Richard III saw the plays.	Stage V. Mr. Chambers, (II, 358) and Mr. Poole, (p. 44) assign this item to 1486.
1487.	Sharp, *Diss.*, p. 164.	Payment to torchbearers and to minstrel on Corpus Christi day. Carpenters' accounts.	Stage V.
1487.	Harris, p. 288.	Henry VII saw the plays.	

DOCUMENTS—Continued.

Coventry.

Date	Document	Content	Interpretation
1489.	Sharp, *Diss.*, p. 167. Craig, p. XVII. Chambers, II, 363.	"It' payd ffor Aroddes garment peynttyng pt he went a p'ssayon in."	Stage VI. See comment on entry 1476. This does not necessarily refer to the Corpus Christi procession. These two references to Herod's riding in the procession are the only ones of their kind that have been found. Note that this does not necessarily mean that the plays developed from the procession.
1492.	Sharp, *Diss.*, p. 9.	Chandlers and Cooks are to contribute to the support of the Smiths' pageant.	Stage V.
1493.	Harris, p. 288. Chambers, II, 358.	Henry VII saw plays.	Mr. Poole, p. 44 gives this date as 1492. Stage V.
1494.	Sharp, Diss., p. 81.	Butchers agree to help "Whittawers" to support their pageant.	Stage V.
1494.	Sharp, *Diss.*, p. 163.	Mention of torch bearers on Corpus Christi day. Dyers' Accounts.	Stage I.
1494.	Sharp, *Diss.*, p. 79.	Carpenters ask for help since they are charged "with a *Pagiant, kepyng wacches*", etc.	Stage V.
1494.	Harris, p. 292.	Dyers refuse to have pageant.	Stage V.
1494.	Poole, p. 40.	Mayor and council to help those overburdened with pageants by unions of crafts.	Stage V.
1494.	Sharp, *Diss.*, p. 10.	Inhabitants of Gosseford Street ask to have pageants stand at the place there.	Stage V.
1495.	Sharp, *Diss.*, p. 10.	Cardmakers ask that the craft of Skinners and Barkers may pay towards the charge of their Pageants. "Wrights," "Tylers," and "Pynners" ask for help in supporting pageant. "Cappers" and "Fullers" are to help "Girdlers" in supporting their pageant.	Stage V.
1497.	Sharp, *Diss.*, p. 20, note.	"'It'm for the horssyng of the padgeant.'"	Stage V.

DOCUMENTS—Continued.

Coventry.

Date	Document	Content	Interpretation
1498.	Sharp, *Diss.*, p. 22. (13 Henry VII.)	"'Also that they [the journeymen of the Craft] wate upon the hede maystr upon Corpus XPi daye to goo upon Pssession also to wate upon the mayst's and *attende upon the pageaunt* to the worsshipe of this cite.'"	The procession and the pageant appear to have been at different times in the day.
1501.	Chambers, II, 363.	"'payd for a Crown of sylver & gyld for the Mare on Corpus Christi day.'"	"The other extant guild records throw no light on the presence of representatives of the plays in the procession, but the Corpus Christi guild itself provided dramtic personages." Chambers, II, 363.
1501.	Chambers, II, 359.	Tilemakers of Stoke contribute to a pageant.	Stage V.
1501.	Sharp, *Diss.*, p. 79.	Every stranger who becomes a member of the craft of "Cottyers & ffletchers" is to pay toward the support of the pageant of the "pynners, Tylers & Cowpers."	Stage V.
1504.	Sharp, *Diss.*, p. 79.	Certain regulations for support of "pynners and Tylers pageant."	Stage V.
1507.	Leet Book, p. 608, 607.	Butchers are to help the "Whittawers" in supporting their pageant. "Corvysers" are to help the Tanners in supporting their pageant. The Bakers are to help the Smiths in supporting their pageant.	This date is given as 1506 in Sharp, *Diss.*, p. 10.
1509.	Leet Book, p. 625.	Same as second reference under 1507.	
1516.	Sharp, *Diss.*, p. 164	"Itm payed for pe breakfast at Morris on Corpus XPi day afore pe going to the procession." Carpenters' Accounts.	Stage I. This helps to determine at what hour the procession was made.
1517.	Chambers, II, 359.	Bequest to tanners for their play.	Stage V.
1518.	Sharp, *Diss.*, p. 161.	"It p'd for beryng of the crosse on—*Corpus XPi day.*"	Stage I.
1519.	Sharp, *Diss.*, p. 11.	New plays.	Stage V.
1519.	Sharp, *Diss.*, p. 163.	Payment of torchbearers on Corpus Christi day. Dyers' Accounts.	Stage I.

DOCUMENTS—Continued.

Coventry.

Date	Document	Content	Interpretation
1520.	Sharp, *Diss.*, p. 163.	Payment for bearing of four torches upon Corpus Christi day. Dyers' Accounts.	Stage I.
1520.	Chambers, II, 358.	New plays.	Stage V.
1523.	Sharp, *Diss.*, p. 11.	"Shoemakers to pay the Tanners 6 s. 8 d. at Corpus XPi as of old."	Stage V.
1523–1533.	Abbotsford, p. 20.	Charges of Corpus Christi day regularly occur in the accounts.	
1526.	Sharp, *Diss.*, p. 11.	Carvers to help support Painters' Pageant.	Stage V.
1526.	Chambers, II, 358.	Tale of preacher who supports sermon by reference to plays.	Stage V.
1529.	Leet Book, p. 697.	Cappers are to have the Weavers' pageant.	Stage V.
1530.	Sharp, *Diss.*, p. 11.	Cappers are discharged of an annual payment to the Girdlers towards their pageant.	Stage V.
1531.	Sharp, *Diss.*, p. 11. Leet Book, p. 710.	Bakers to help Girdlers support their pageant and processions. Walkers and Skinners to help Weavers support their pageant.	Stage V.
1531.	Leet Book, p. 708.	Cappers to be associated with Cardmakers and Sadlers in supporting their pageant. Barbers to help Girdlers support their pageant.	Stage V.
1532.	Sharp, *Diss.*, p. 11.	Painters to contribute to pageants of Girdlers and Cardmakers.	Stage V.
1533.	Leet Book, p. 716.	All men to associate to some craft charged with a pageant.	Stage V.
1535.	Chambers, II, 361.	Croo corrected the Shearmen and Tailors' Play.	Stage V.
1537.	Poole, p. 40. Sharp, *Diss.*, p. 11.	Transfer of pageant and pageant house of Cardmakers and Saddlers to fraternite of Cappers.	Stage V.
1539.	Chambers, II, 358.	Expenses of plays made people poor.	Stage V.

DOCUMENTS—Continued.

Coventry.

Date	Document	Content	Interpretation
1539.	**Sharp, p. 164 ff.** Chambers, II, 363.	"'Peny bred for the appostells, vjd beiff for the apposteles, viijd to the Marie for hir gloves and wages, ijs. the Marie to offer, jd. Kateryne & Margaret, iiijd. viij virgyns, viijd. to Gabriell for berying the lilly, iiijd. to James & Thomas of Inde, viijd. to X other apostells, XXd.	Stage VI? Craig, p. XVI, p. XVII, thinks there was a play in the procession of Corpus Christi. See also Harris, p. 287. These items are from the accounts of the united *religious* gilds. As at Chester, this play (if it was one) may have been entirely distinct from the craft plays. See entry 1501.
1547.	Sharp, p. 79.	Coopers to associate with Tilers and Pinners in supporting pageant.	
1547.	Sharp, *Diss.*, p. 11.	Cowpers to help Tilers and Pinners support their pageant. "Whittawers" hire Cappers' pageant.	
1554.	Sharp, *Diss.*, p. 164.	"p'd to the mynstrells for prosesyon and pageants."	Stage I, Stage V. This indicates that the procession and plays were distinct.
1565.	Sharp, *Diss.*, p. 49.	Cost and charge of pageant.	
1573.	Sharp, *Diss.*, p. 36.	Smiths' new play.	Stage V.
1574. 1580.	Chambers, II, 358.	Pageants played regularly to 1580, except in 1575.	Stage V.
1587.	Abbotsford, p. 21. Chambers, II, 358.	"Padgent" of weavers sold.	Stage V.
1591.	1. Abbotsford, p. 21. 2. Chambers, II, 361.	1. "Payd to mayor for padgantes." 2. Old Corpus Christi plays proposed for exhibition.	
1593.	Abbotsford, p. 21.	"It p when we reseved moneye for players aparele".	
1606.	Abbotsford, p. 21.	"It p at Pyringes when we hired our aparel to Thomas Masie."	
1607.	Abbotsford, p. 21.	"Apparell" lent.	

Conclusion: The plays are first mentioned in 1392; the procession in 1348, when it was apparently under the control of the Corpus Christi Gild. There is no indication that between 1348 and 1392 the plays were part of the procession, either as mute mysteries or as spoken drama. The length of the plays makes it probable that after 1392 at least, they were distinct from the procession. The puzzling entries in 1476 and 1489 may mean (and this would substantiate Mr. Spencer's theory) that, after the separation of the plays from the procession, characters from the pageants continued to ride in the procession. The relationship, however, may be no more than external. The two items are exceptional. I have interpreted the entries for 1501 and 1539 as follows: At Coventry (as at Chester the "prestes" and "colleges"), the religious gilds performed in the procession a play that had no connection with the craft plays. To conclude—while we have at Coventry stages I, V, and VI, there is no evidence that the development followed the consecutive stages I, II, III, IV, V.

DOCUMENTS.

Dublin.

Date	Document	Content	Interpretation
1498.	Chambers, II, 363.	"The Chain Book of the City contains the following memorandum,—Corpus Christi day a pagentis:—"The pagentis of Corpus Christi day, made by an olde law and confermed by a semble—: 'Glovers: Adam and Eve, with an angill followyng berryng a swerde. Peyn XL.s. 'Corvisers: Caym and Abell, with an auter and the offerance. Peyn XL. s. 'Maryners, Vynters, Shipcarpynderis, and Samountakers: Noe, with his shipp, apparalid accordyng. Peyn, XL. s. 'Wevers: Abraham [and] Ysaak, with ther auter and a lamb and ther offerance. Peyn, XL. s. 'Smythes, Shermen, Bakers, Sclateris, Cokes and Masonys: Pharo, with his hoste. 'Skynners, House-Carpynders, and Tanners, and Browders: for the body of the Camell and Oure Lady and her chil[d]e well apereled, with Jo-	"These pageants,—appear from their irregular order, to be only dumb-show accompaniments of a procession." Chambers, II, 365. Stage III, IV, or V?

DOCUMENTS—Continued.

Dublin.

Date	Document	Content	Interpretation
		seph to lede the Camell, and Moyses with the children of Israell, and the Portors to berr the Camell. Peyn, XL. s. and Steyners and Peyntors to peynte the hede of the Camell. (Peyn,) XL. s. '[Goldsmy] this: The three kynges of Collynn; ridyng worshupfully, with the offerance, with a sterr afor them. '[Hoopers]: The shep[er]dis, with an Angill syngyng Glorea in excelsis Deo.— 'Corpus Christi yild: Criste in his Passioun, with three Maries, and angilis berring serges of wex in ther hands.— 'Taylors: Pilate, with his fellaship, and his lady and his kynghtes, well beseyne.— 'Barbors: An[nas] and Caiaphas, well araied acordyng.— 'Courteours: Arthure, with [his] knightes— 'Fisshers: The Twelve Apostelis.— 'Marchauntes: The Prophetis— 'Bouchers: tormentours, with ther garmentis well and clenly peynted.— 'The Maire of the Bulring and bachelers of the same: The Nine Worthies ridyng worshupfully, with ther followers accordyng.— 'The Hagardmen and the husbandmen to berr the dragoun and to repaire the dragoun a Seint Georges day and Corpus Christi day.' "	
1569.	Chambers, II, 365.	"In 1569 the crafts were directed to keep the same order in the Shrove Tuesday ball riding (—) 'as they are appointed to go with their pageants on Corpus Christi daye by the Chayne Booke.' "	

Conclusion: From these two references it is difficult to judge of the nature of the "pagentis." Since the Corpus Christi procession is not mentioned, I am inclined to think that the quotations describe spoken drama.

DOCUMENTS.

Hereford.

Date.	Document.	Content.	Interpretation.
[1500 to 1520?]	Hist. Mss., XIII, pt. 4, p. 304.	" 'To the ryght worshypeful mayer of the cytey of Herefford and to hys bretherne. Shewythe unto your good mastershippes your umble orators the persons subscribed beyng journemen of th' occupacion of corvesers within this cytey have obtayned of your mastershippes predecessors mayers and aldermen of the seyd cytey a composysyon whereby your sayd orators were bound to bryng furth certen torches in the procession on the day of Corpus Christi yerelye' "—.	Stage I.
1503.	Hist. Mss., XIII, pt. 4, p. 288, 9.	" 'The paiants for the procession of Corpus Christi Furst, Glovers—Adam, Eve. *Cayne and Abell* (erased). Eldest Seriant—Cayne, Abell, and Moysey, Aron, Carpenters—Noye ship. Chaundelers—Abraham, Isack, Moysey. Bakers—Knyghtes in harnes. Journeymen Cappers—Seynt Keterina with tres(?) tormentors!"	"The 1503 list seems to concern a dumb show only." Chambers, II, 368. Stage III.
1549.	Hist. Mss., XIII, part 4, p. 305. Devlin, p. 65.	" 'fforasmuche as ther was before thys tyme Dyvers corporacions of Artiffycers, craftes, and occupacions in the sayd cytty who were bounde by the grante of their corporacions yerelye to bryng fforth and sett forward Dyvers pageauntts of Auncyentt historyes in the processions in the sayde cytty upon the Day and ffeast of Corpus Xti [—], which nowe ys and are omytted and surceased, whereof it ys Agreed, condescended, and granted that all and everye of the sayd craftes and corporacions shall in stede and place of the settynge fforthe of the sayd pageauntts on the sayd daye or ffeast of Corpes Xti, yerely consente to pay att the ffeaste of the Annuncyacion—one Annuyte—to the vse—of the sayd ctey.' "	Stage III or Stage IV.

Conclusion: At Hereford, to judge from the material we have, certain mute mysteries were performed in the course of the Corpus Christi procession through the city. The quotations are too late, however, to help the theory very strongly.

DOCUMENTS.

Ipswich.

Date	Document	Content	Interpretation
1325.	Hist. Mss., IX, pt. 1, p. 245. Chambers, II, 371.	The constitution of Corpus Christi guild provides for a procession on Corpus Christi Day.	Guild of Corpus Christi included all burgesses. Stage I. Stage V? Chambers, II, 371.
1443.	Chambers, II, 372.	"In 1443 the common marsh was devised 'to maintaine and repaire the pageants of the Guilde.'"	Stage V?
1445.	Chambers, II, 372.	"Causton to maintain for seven years 'the ornaments belonging to Corpus Xi pageant—.'" "Arrears were paid to J. Caldwell for his charge of 'Corpus Chr. pageant.'"	Stage V?
1491.	Hist. Mss., IX., Pt. 1, p. 241. Chambers, II, 372.	List of occupations and callings entitled "'Howe every occupacion of craftsmen schuld order themselves in the goyng with their pageantes in the procession of Corpus Christi.' The programme shows that the processions closed with the "Friers Carmelites", "Friers Minors," and "Friers Prechors." In handwriting of Henry the Seventh's time."	"The pageantes" may refer to the plays or to the pageant wagons, to stage III, to Stage IV, or to Stage VI.
1492.	Chambers, II, 372.	"In 1492 'areres of ye Pageant' were paid, and 'kepers of the Ornaments and utensiles of Corpus Christi appointed.'"	Stage V?
1493.	Chambers, II, 372.	Order for provision of 'pageant.'	Stage V?
1494.	Chambers, II, 372.	Order for provision of 'pageant.'	Stage V?
1495.	Chambers, II, 372.	Order for provision of 'pageant.'	Stage V?
1496.	Chambers, II, 372.	Order for provision of 'pageant.'	

DOCUMENTS—Continued.

Ipswich.

Date	Document	Content	Interpretation
1502.	Chambers, II, 372.	"'Corpus Christi pageant shall hereafter be observed.'"	Stage V?
1504.	Chambers, II, 372.	Collectors for play "'to make a free burgess for their expences at Corpus Christi play.'"	Stage V?
1505.	Chambers, II, 372.	Collectors for play mentioned.	Stage V?
1506.	Chambers, II, 372.	Collectors for play mentioned.	Stage V?
1506.	Chambers, II, 372.	"'Ornaments' and 'Stageing for Corpus Christi play'" mentioned.	Stage V?
1509.	Chambers, II, 372.	1. "All inhabitants are to have their Tabernas and attendance at the ffeast on Corpus Christi.'" 2. "'Everyone shall hold by the order of their procession, according to the Constitutions.'"	Stage I?
1511.	Chambers, II, 372.	Corpus Christi pageant laid aside.	
1513 to 1519.	Chambers, II, 372.	Play ordered to be laid aside except in 1517.	
1520.	Chambers, II, 372.	Pageant ordered to be made ready.	
1521.	Chambers, II, 372.	Pageant laid aside. Master of pageant called 'the shipp' to have the same ready.	Stage V?
1522.	Chambers, II, 372.	Pageant 'deferred.'	
1531.	Chambers, II, 372.	Pageant 'laid aside for ever.'	
1540.	Chambers, II, 373.	"There is an order for the procession with the Sacrament in 1540."	Stage I.
1542.	Chambers, II, 373.	In 1542 the procession "had its 'pageants' to which each house holder was rated at 1 d."	Stage III, Stage IV, or Stage VI.

Conclusion: Until the meaning of the word "pageantes" is determined, one can not tell whether the plays were performed during the procession, or whether the pageant wagons were merely drawn in the procession and the plays performed later in the day.

DOCUMENTS.

King's Lynn.

Date	Document	Content	Interpretation
1385.	Chambers, II, 374.	Chamberlain's accounts of 1385 include: "'11js 111jd to certain players, playing an interlude on Corpus Christi day.'"	Was this play given by the crafts?
1449.	Hist. Mss., XI, pt. 3, p. 165, 166.	The Tailor's Ordinances order certain fees and fines to go to the support of the procession of Corpus Christi.	Stage I.
1462.	Hist. Mss., XI, pt. 3, p. 224. Chambers, II, 374.	"iis paid for two flagons of red wine, spent in the house of Arnulph Tixonye by the Mayor and the most of his brethren, being there to see a certain play at the Feast of Corpus Christi."	Stage V.
1462.	Hist. Mss., XI: pt. 3, p. 225.	"XXs. given by way of reward to the Skinners of the town for their labour about the procession at the Feast of Corpus Christi, this year."	Stage I. The procession and the plays seem, in 1462, to have been separate.

Conclusion: The evidence is too meagre to be conclusive.

DOCUMENTS.

Lincoln.

Date	Document	Content	Interpretation
1328.	T. Smith, English Gilds, p. 182.	Gild of the Tailors—"All the bretheren and sisteren shall go in procession on the feast of Corpus Christi."	Stage I.
1471–2.	Chambers, II, 378.	Local annals record play 1471–2. "Ludus Corporis Christi."	Stage V?
1473–4.	Chambers, II, 378.	Same as entry 1471–2.	Stage V?
1478–80.	Chambers, II, 378.	"'In commun' canonicorum Existent' ad videndum ludum Corporis Christi in camera Iohannis Sharpe infra clausam, 17 s. ii d.'"	"The Corpus Christi play, although so called, would appear not to have been played upon Corpus Christi day, but to be identical with the visus or 'sights' of St. Anne's day (July 26.)" These were "cyclic and processional." Chambers II, 378.

DOCUMENTS—Continued.

Lincoln.

Date	Document	Content	Interpretation
1515.	Spencer, p. 81.	"At Lincoln in 1515 the players not only were required to go in character in the procession, but constables were stationed 'to wait upon the array in procession, both to keep the people from the array, and also to take heed of such as wear garments in the same.'"	1515, 27 July.—"It is agreed that whereas divers garments and other 'heriorments' are yearly borrowed in the country for the arraying of the pageants of St. Anne's Guild, but now the knights and gentlemen are afraid with the plague so that the 'graceman' cannot borrow such garments, every alderman shall prepare and set forth in the said array two good gowns and every sheriff and every chamberlain a gown, and the persons with them shall wear the same. And the constables are ordered to wait upon the array in procession, both to keep the people from the array, and also to take heed of such as wear garments in the same." Hist. Mss., XIV, pt. 3, p. 25.
1518.	Spencer, p. 62.	"In the early years of the Corpus Christi festival, when the procession and the plays were all one, the ceremonies of the day seem to have begun at an early hour in the morning.—What the exact hour was in the earliest years of the procession we do not know.—At Lincoln in 1518 it was at seven o'clock in the morning."	1518, 16 June. "Ordered that every alderman shall send forth a servant with a torch to be lighted in the procession with a rochet upon him about the Sacrament,—And also send forth one person with a gown upon his back to go in the procession. That every constable shall wait on the procession on St. Anne's day by 7 of the Clock, upon pain of forfeiture of 12 d." Same, p. 26. I do not believe that the two entries for 1515 and 1518 refer to the Corpus Christi procession for these reasons: 1. The procession is evidently the procession on St. Anne's day. 2. The dates of the enactments (June, July) are more appropriate for St. Anne's day than for Corpus Christi day.
1554–5.	Chambers, II, 379.	In 1554 and 1555 "'it was ordered that St. Anne's Gild with Corpus Christi Play shall be brought forth' and played this year.'"	

Conclusion: The plays and the procession at Lincoln were evidently on different days. After ruling out the quotations for 1515 and 1518, one has little material on which to base any conclusion. Between 1328 and 1478, the play may have been given on Corpus Christi Day. In the sixteenth century the plays were certainly on St. Anne's day. Mr. Leach (in *A Miscellany Presented to Dr. Furnivall*, p. 226) notes that the play of St. Anne did not differ much from the Corpus Christi plays. The close relation between the St. Anne procession and the play of St. Anne may then be an argument for a similar close relation between the Corpus Christi procession and the Corpus Christi plays.

DOCUMENTS.

London.

Date	Document	Content	Interpretation
1327ff.	Davidson, p. 93. See Sharp, p. 168, note.	The fraternity of the Gild of Corpus Christi established in 1327 had an annual procession on Corpus Christi day. After the two hundred priests and clerks came the cheriff's servants, the clerk of the Compters, the chaplains for the sheriffs, the mayor's sergeants, the counsel of the city, the mayor and aldermen in scarlet, and then the Skinners.	The Corpus Christi Gild had charge of this procession.
1389.	Riley, Memorials of London, p. 509.	"Because that by the reputable men of the Parish of St. Nicholas Acon, Nicholas Twyford, Knight, Mayor of the city of London, was given to understand that, whereas, they, time out of mind, had been wont and accustomed to have free ingress and egress with their procession, on the befitting and usual days, through the middle of a certain house belonging to John Basse,—the aforesaid John, together with John Creek, draper, and others of their covin, on Thursday, the feast of Corpus Christi last past, —would not allow the parishioners of the church of St. Nicholas aforesaid to enter the house with their procession as they has been wont to do."	This procession seems to have been purely ecclesiastical.

DOCUMENTS—Continued.

London.

Date	Document	Content	Interpretation
1477–9.	Littlehales, p. 81.	Garlands for procession.	See comment on preceding.
1478–81.	Littlehales, p. 100.	Flags, garlands, torches for procession.	See comment on preceding.
1487–88.	Littlehales, p. 131.	Laten bells for canapye on Corpus Christi day.	See comment on preceding.
1489–90.	Littlehales, p. 149.	Children for the procession.	See comment on preceding.
1491–2.	Littlehales, p. 173.	Roses for the procession.	See comment on preceding.
1519–20.	Littlehales, p. 305.	Garlands for the procession.	See comment on preceding.
1523–24.	Littlehales, p. 322.	Garlands for crosses and chair and for strangers who bore "copis".	See comment on preceding.
1524–25.	Littlehales, p. 330.	Bearing of crosses on Corpus Christi day.	See comment on preceding.
1548.	Nichols, *Grey Friars Chronicle.*	"This same yere was put downe alle goyng abrode of processyons,—and the skynners' processyon on Corpus Christi day."	See comment on preceding.
1554.	Same, p. 89.	"Item the XXIIIj day of May was Corpus Christi day that some kepte holy day and some wolde not, and there was a joyner—he was in Smythfelde when the procession of sent Pulchers came by hym, and he wold a tane the sacrament from the prest."	See comment on preceding.
1557.	L. T. Smith, York Plays, p. LXIV.	Passion of Christ given on Corpus Christi day.	

Conclusion: There is only one mention of a play on Corpus Christi day; so that it is difficult to connect it with the procession, which seems to have been in charge of the individual churches, and of a religious gild, not of the crafts.

DOCUMENTS.

Newcastle.

Date	Document	Content	Interpretation
1426–7.	Chambers, II, 385.	Corpus Christi plays first mentioned.	Stage V.
1436.	Brand, *Newcastle,* II, 370.	Corpus Christi play mentioned in ordinaries of smiths and glovers.	Stage V.
1437.	Brand, *Newcastle,* II, 370, note.	Skinners' ordinary mentions plays.	Stage V.
1442.	Brand, *Newcastle,* II, 370.	Plays mentioned in ordinary of barbers.	Stage V.
1451.	Brand, *Newcastle,* II, 370.	Plays mentioned in ordinary of slaters.	Stage V.
1454.	Chambers, II, 424.	*Creation of Adam* and *Flight into Egypt* played by Bricklayers and Plasterers.	Stage V.
1459.	Brand, *Newcastle,* II, 370.	Plays mentioned in ordinary of sadlers.	Stage V.
1477.	Brand, *Newcastle,* II, 370.	Plays mentioned in ordinary of fullers and dyers.	Stage V.
1479–80.	Surtees, Vol. 93, p. 4. 20 ED. IV. Brand, *History and Antiquities of Newcastle,* II, 371.	"Also it is asentit, —by the said Felleship, —that wppon Corpus Christi Day yerly, in honoryng and worshippyng of the solemp procession, every man of the said Felleship beyng within the franches of this town the said day as it shall fall, shalle apper in the [Beer *interlined*] Marcoth by VIj of clok in the mornyng.—Also that thair be a rowll mayd of all the names of the same Fellowship, for the said procession, and accordyng to that rowll callyd by the Clark, the lattast mayd burges to go formest in the procession—Provyded always that all those of the said Felleship that shalbe Mair, Shereff, and aldermen, with thaire officers and servandes, than beyng, attend wppon the holy sacramente. Provydet also, that all those of the said Felleship as beyn maires, shereffs, and aldermen in yerys by passyt, shall go principall in the sayd solemp procession, accordyng as they war chossen into the sayd officese."	The plays were apparently processional. The pageants may first have taken part in the Corpus Christi procession proper and afterwards have gathered in a field. Chambers, II, 385. "The difficulty seems to have been solved at Newcastle by sending the pageants around with the procession in the early morning and deferring the actual plays until the afternoon." Chambers, I, 162. Stage I.

DOCUMENTS—Continued.

Newcastle.

Date	Document	Content	Interpretation
1536,	Brand, *Newcastle,* II, 371.	Group of companies ordered to play *Three Kings.*	Stage V.
1536.	Chambers, II, 385.	Regulations of Tailors for support of play.	Stage V.
1552.	Brand, *Newcastle,* II, 371.	Merchant Adventurers concerned in five plays.	Stage V.
1561.	Brand, *Newcastle,* II, 371.	"Item for the care and banner berryng 20 d."	Stage V?
1561.	Surtees, Vol. 50, 299.	Linen " 'for God's coat purchased.' "	Stage V.
1561, 1562.	Chambers, II, 385.	1561, 1562 last years in which performances can be proved to have been given.	Stage V.
1568.	Brand, *Newcastle,* II, 370.	"Item, for bearers of the care and baneres."	Stage V?
1568.	Brand, *Newcastle,* II, 370. Surtees, Vol. 50, 299.	Play of slaters was *Offering of Isaac.*	Stage V?
1578.	Brand, *Newcastle,* II, 372.	Whenever the general plays are commanded by the mayor, the millers are to play the *Deliverance of the Children of Isrell.*	Stage V.
1579.	Brand, *Newcastle,* II, 372.	Whenever the general plays of the town are played, the carpenters are to play the *Burial of Christ.*	Stage V.
1581.	Brand, *Newcastle,* II, 372.	Whenever the general plays of the town are played, the masons are to play the *Buriall of our Lady.*	Stage V.
1589.	Brand, *Newcastle,* II, 372.	Whenever general plays of the town are played, the joiners shall attend to same.	Stage V.
1578–1589.	Surtees, Vol. 50, 299.	Corpus Christi plays on the decline.	Stage V.

Conclusion: The plays and the procession at Newcastle seem to have been distinct. The items for 1561 and 1568 may represent stage VI, but more probably they refer to the processional nature of the plays.

DOCUMENTS.

Norwich.

Date	Document	Content	Interpretation
1478.	Chambers, II, 386.	J. Whetley writes from Norwich on Corpus Christi day "'at hys beyng ther that daye ther was never no man that playd Herrod in Corpus Christi play better and more agreable to his pageaunt than he dud.'"	Stage V.
1489.	Waterhouse, p. XXX–XXXI. Chambers II, 389.	In 1849 it was ordered that the thirty-one guilds of the town, on Corpus Christi Day, should go in procession before the pageants "'ad Capell, in Campis Norwici, modo sequi.'" The procession was arranged in the following order: the thirty-one guilds, the pageants, the *Shreves clothing, Mr. Shreve*, the Mair's *clothing, Maister Mair* and *Maister Aldermen with bokes or beads in their hands.*	Note in Waterhouse p. XXIX: The pageants are "referred to always as *the procession*." There is no proof that by *procession* is meant *pageants.*
1527.	Waterhouse, p. XXIX.	"For some time previous to 1527, the St. Luke's Guild, consisting of the pewterers, braziers, plumbers, bellfounders, glaziers, steyners and several other crafts, had apparently become responsible for the entire management of, and outlay in connection with, the Corpus Christi plays; and in that year, finding themselves, as a result of this, almost in a bankrupt condition, they petitioned the corporation to divide the responsibility and expense among the various guilds."	In 1527 St. Luke's guild urges that "'where of longtime paste the said Guylde of Seynt Luke yerely till nowe hath ben used to be kept and holden within the citie aforesaid upon the Mundaye in pente coste weke at which daye and the daye next ensuying many and divers disgisyngs and pageaunts—that every occupacion wythyn the seyd citye maye yerly at the said procession upon the Mondaye in Pentecost weke sette "forth one pageaunt.'" Chambers, II, 387. Mr. Waterhouse has evidently misinterpreted the passage.
1534.	Chambers, II, 387.	4 surveyors of pageant of grocers chosen. Assessment made on Grocers "for the pageant and the Corpus Christi procession."	Stage I and Stage V. The procession and the plays were apparently separate.
1535.	Waterhouse, p. XXXI.	Performance of Corpus Christi play.	Stage V.
1536.	Waterhouse, p. XXXI.	Performance of Corpus Christi play.	Stage V.

Norwich.

DOCUMENTS—Continued.

Date	Document	Content	Interpretation
1538.	Waterhouse, p. XXXI.	Performance of Corpus Christi play.	Stage V.
1539.	Waterhouse, p. XXXI.	Performance of Corpus Christi play.	Stage V.
1540.	Waterhouse, p. XXXI.	Surveyors apparently contracted for the performance of the plays.	Stage V.
1541.	Waterhouse, p. XXXI.	Plays apparently performed.	Stage V.
1542.	Waterhouse, p. XXXI.	Plays apparently performed.	Stage V.
1546.	Waterhouse, p. XXXIII, note.	" 'Accordyngly were chosen 4 Aldermen & 8 Comyners—; 2 Wardeyns & 2 Surveyors for settyng forth þe Procession on Corpus Xi day, & for þe Pageant yf it go forth þe next year.' "	Stage I and Stage V. The procession and the plays seem to have been distinct.
1546.	Waterhouse, p. XXXI.	After 1546 plays waned.	
1556.	Chambers, II, 385.	From 1556 on " 'Gryffon,' 'Angell,' and Pendon' of the Corpus Christi procession, with flowers, grocery, and fruit 'to garnish ye tre wth' &., appear alone in the accounts." (Grocers')	Stage II. It does not appear that the pageants had any connection with this procession.
1558.	Chambers, II, 389.	Corpus Christi procession mentioned in grocers' records until 1558. "They seem to have been represented by the 'griffon' from the top of their pageant, a banner with their arms, a crowned angel, and an emblematic tree 'of fruit, and grocery.' "	Does emblematic tree indicate a play in the procession?

Conclusion: The plays and the procession during the period covered by the available documents seem to have been distinct. Both statements:—that plays were performed in the procession, and that the pageant wagons were drawn in it,—are mere conjectures.

DOCUMENTS.

Salisbury.

Date	Document	Content	Interpretation
c. 1445.	Wordsworth, *Salisbury Processions,* p. 95.	Salisbury processional for Corpus Christi day.	In book written about 1445. Introduction to Wordsworth, *Salisbury Processions,* p. XVII.
c. 1461.	Chambers, II, 393.	" 'The churchwardens' accounts of St. Edmund's for 1461 include an 'item for all apparel and furniture of players at the Corpus Christi.' "	

Conclusion: Both procession and play seem to have remained in the hands of the church.

DOCUMENTS.

Shrewsbury.

Date	Document	Content	Interpretation
1461.	Hist. Mss., XV, pt. 10, p. 11.	Agreement between Fletchers, Cowpers, and Bowers on the one part and the Carpenters on the other as to the order in the procession on Corpus Christi day of their banner, wax, and alderman respectively."	Stage II.
1478.	Hibbert, p. 59.	Companies of Millers, Bakers, Cooks, Butchers and Shearmen took part in the Corpus Christi procession in 1478.	Stage I.
1480.	Owen, p. 63.	Mercers were to have a candle carried before the sacrament in the procession of Corpus Christi.	Stage I.
1517–8.	Hist. Mss. XV, pt. 10, p. 32.	"In vino expendito super tres reges Colonie equitantibus in interludio, pro solacio ville Salop in festo Pentecost, iiij d. et in vino dato abbati Salop et famulis suis ad generalem processionem, in festo Corporis Christi."	Stage I.
1521.	Owen and Blakeway, I, 292.	In vino dat' Epo Coventr' & Lich' p'sedent' consilii dni R' in Marchiis Wallie & aliis commissionariis dni R'ad gen' alem p' cessionem in festo Corp'is Xpi hoc ao."	Stage I.

DOCUMENTS—Continued.

Shrewsbury.

Date	Document	Content	Interpretation
1546-7.	Hist. Mss., XV, pt. 10.	"Pro vino et tortis datis ballivis et associatis suis in festo Corporis Christi euntibus in processione."	Stage I.
?	Owen, p. 64.	"Preceded by their Masters and Wardens, and graced with 'colours" the companies "attended the Bailiffs and members of the Corporation, who with the Canons of St. Chad and St. Mary, the Friars of the three convents, and the Parochial Clergy, followed the holy Sacrament" on Corpus Christi day.	Stage I.
?	Saloplan, p. 11.	The Tailors had at one time in the procession "Adam and Eve, before whom a large bough was borne, from which an apple was occasionally plucked; and two knights with drawn swords.	If this statement is authentic, it refers to Stage III.
	Sharp, p. 171. Owen, p. 65.	Procession of crafts with emblematical devices.	Before Reformation, tableaux were usually of a biblical or ecclesiastical nature; after of mythological or historical. Hibbert, p. 117.
?	Hist. Mss., XV, pt. 10, p. 10.	" 'Ordinacio processionis artificum ville Salopie in festo Corporis Christi.' The companies were in the following order: Molendinarii, Pistores, Piscatores, Coci, Carnifices, Barcarii, (Tanners), Cordewenarii, Fabri, Celarii, Carpentarii, Flechers, Cowpers and Bowers, Textores, (T)onsarii cum Barbitonsoribus [Ci]rotecarii, [Sci]ssores."	Stage I.

Conclusion: There is no evidence that the procession ever developed beyond stage II or at most stage III. I found no reference to spoken drama on Corpus Christi day.

DOCUMENTS.

York.

Date	Document	Content	Interpretation
1376.	$\frac{A}{y}$, p. 10.	"De uno tenemento, in quo tres pagine Corporis Christi ponunter, per annum—ij s."	In a hand of the 16th or the 17th century. Stage V.
1378.	L. T. Smith, p. XXXI.	"The earliest notice of the Corpus Christi plays in York, yet found is in 1378."	Stage V.
1388.	Davies, p. 230.	" 'William de Selby, then Mayor, delivered to Stephen de Molton, 100 shillings, which Master Thomas de Bukton had given for furnishing four torches to be burnt in the procession on the feast of Corpus Christi."	Stage I.
1390.	$\frac{A}{y}$, p. 115.	Any craftsman who takes apprentice must pay toward pageant.	Stage V.
1394.	p. 47. See also L. T. Smith, p. XXXII. Davies, p. 230.	"Eodem die concordatum est quod omnes pagine Corporis Christi ludent in locis antiquitus assignatis et non alibi."	Stage V.
1397.	Davies, p. 230. L. T. Smith, p. XXXII.	Richard II saw plays.	Stage V.
1399.	Davies, p. 231, 232.	Order of stations definitely established, beginning at the gates of the priory of the Holy Trinity in Micklegate. The 10th station was the gates of St. Peter, the 11th, the end of Gyrdlergate in Petergate, and the 12th, the Pavement.	Stage V.
1399.	Davies, p. 232. $\frac{A}{y}$, p. 44.	Order made that all persons "as had—summer garments of the worshipful men of the city should go with mayor and worshipful men on the feast of Corpus Christi, in procession to the church of St. Peter and the hospital of St. Leonard, and that they should have their torches borne and lighted before the procession every year."	Stage I. The procession and the plays appear to have been connected in 1399, since the course of the two through the city seems to have been the same.

DOCUMENTS—Continued.

York.

Date	Document	Content	Interpretation
1403.	Hist. Mss., I, 109.	" 'All *hosyers* who shall sell hose [—] or make hose to sell, together with the *uphaldres* who before have sold woolen cloths, shall have charge of the pageant of Moses and Pharoah at the holiday of Corpus Christi, as well as the *dubbers.*' "	Stage V.
1404–1405.	A/y, p. 107.	"Et auxi que enchescun an que le mair envoiera la bille de lour pagyne de Corpore Christi as gentz del dit artifice, sicome est la custume de la citee, touz les meistres du dit artifice assembleront en certein place par le temps assigne, et illeoques ordeigneront pur lour pagyne et lour lumer et les payntes et la arraie dicelle."	Stage V.
1408.	Register of Corpus Christi Guild, pp. 6, 8. Smith, *Eng. Gilds,* p. 141.	"Ordinamus quod in festo Corporis Christi omnes capellani in superpellicis transeant in processione—antiquatis ordine."	Stage I (?)
1409.	Antiquary, XI, 107.	"Þe Padzhand maistres of þe said craft salle warne alle þe crafte als oftetymes als þai salle be charged be þe sayd Sercheours."	Stage V.
1403.	Surtees, CXX, 59.	Same as 1390.	Stage V.
1415.	L. T. Smith, *York Plays,* p. XIX–XXVII.	Roger Burton's list of plays.	Stage V.
1417.	Surtees, CXX, 189	"Item ordinatum est quod duodecim honesti viri predicti artificii vadant annuatim in festo Corporis Christi cum pagina sua, secundum quod limitabuntur per quatuor magistros ejusdem artificii."	Stage V.
1417.	Smith, *York Plays,* p. XXXII–XXXIII.	Twelve stations appointed for the Corpus Christi play.	Stage V.
1419.	Surtees, CXX, 109	Foreign tapiter who comes into craft, to help support pageant.	Stage V.
1422.	Davies, p. 235.	Certain pageants to be combined.	Stage V.

DOCUMENTS—Continued.

York.

Date	Document	Content	Interpretation
1426.	Sharp, *Dissertation,* pp. 133, 134.	"'Whereas for a long course of time the artificers and tradesmen of the city of *York* have, at their own expence, acted plays; and particularly a certain sumptuous play, exhibited in several pageants, wherein the history of the old and new testament in divers places of the said city, in the feast of *Corporis Christi,* by a solemn procession is represented in reverence to the sacrament of the body of Christ. Beginning first at the great gates of the holy *Trinity* in *York,* and so going in procession to and into the Cathedral Church of the same; and afterwards to the hospital of St. *Leonard,* in *York,* leaving the aforesaid sacrament in that place.'" Friar Melton induces the people to have the play on one day and the procession on the second.	Stage IV(?) If the word *procession* refers to the Corpus Christi procession and not to the processional nature of the cycle, we have here very definite evidence for stage IV of the Davidson-Spencer theory. The courses of the procession and of the plays are suspiciously alike. See entries for 1399. After 1426 the plays were separated.
1428.	Antiquary, XI, 108	Smiths charge marshals with not paying their pageant silver. Finally agreed that they shall "of thair bather costages bryng furthe pair bather playes, and uphold thair torches in ne procession of Corpus Xpi day."	
1430–1440	....	Register .	Stage V.
1431.	Register of Guild of Corpus Christi, p. 251, 252.	"Agreement between the mayor and citizens of York and the keepers of the Guild [of Corpus Christi] about carrying the shrine in the annual procession on the feast of Corpus Christi."	Stage V.
1443.	Antiquary, XI, 108	Same as 1428.	Stage V.
1475.	Surtees, CXX, 134	Those who are to help girdlers bring out pageant mentioned.	Stage V.
1477.	Surtees, CXX, 134	Certain fines in craft of cutlers to go to the support of their pageant.	Stage V.

DOCUMENTS—Continued.

York.

Date	Document	Content	Interpretation
1478.	Davies, (18 Ed. IV), p. 75 ff.	"And in expenses incurred this year by the mayor, aldermen, and many others of the council of the chamber at the Feast of Corpus Christi, seeing and directing the play in the house of Nicholas Bewyk, according to custom—and 3s. 4d. paid to one preaching and delivering a sermon on the morrow of the said feast, in the cathedral church of St. Peter of York, after the celebration of the procession."	Stage V. This quotation shows that in 1478 procession and plays were distinct.
1478.	Davies, p. 18, 63, 65. (18 Ed. IV.)	Paid for banner for Corpus Christi play. Paid for repair of banners of Corpus Christi play.	Stage V.
1479–1480.	Surtees, CXX, 135.	Certain fines in crafts of cutlers and bladesmiths to go to support of their pageants.	Stage V.
1483–1484.	Hist. Mss., I, 108.	Innholders contract for a space of eight years following to bring forth yearly their pageant of the Coronation of Our Lady.	Stage V.
1485.	Surtees, CXX, 186	Those who shall contribute to pageant of girdlers enumerated.	
1490.	Surtees, CXX, 201	Certain fines in craft or ironmongers to go to support of pageant. Those who are to assist ironmongers in supporting pageant named.	Stage V.
	Same, p. 202.	The pageant of the ironmongers needs repairs.	Stage V.
1493.	L. T. Smith, *York Plays*, p. XLI.	All the masters of the craft of the "Spuriers and Lorymers" " 'shall attend vppon yer paiaunt' " from the beginning of the play to the end.	Stage V.
1493.	Davies, p. 257.	Award to craft of cordwainers that " 'when the procession were solempnely done the morowe next after Corpus Xpi day, to bere their torches honestly made and lighted with the craft of the weavers and going of the weavers' left handes, as had been there afore acustomed.' "	In 1493, the plays and the procession were separate.

DOCUMENTS—Continued.

York.

Date	Document	Content	Interpretation
1501.	Antiq., XXIII, 29.	Thomas Drawswerd was admitted into Holy Trinity Guild on the condition " 'that the said Thomas shall mak the Pagiant of the Dome belonging to the Mrchaunts of newe substanciale in eury thing pr vnto belonging.' "	Stage V.
1505.	Eng. Hist. Rev. IX, 301.	Drapers ask for help in supporting their pageant.	Stage V.
1535.	Davies, p. 258.	Performance of Corpus Christi play suspended.	Stage V.
1547.	Davies, p. 260.	Fines on gildmen for not furnishing torches for " 'procession the Friday after Corporscristy day.' "	In 1547, the plays and the procession were distinct.
1548.	Davies, p. 262.	Plays given except pageant of " 'the denyng of our lady, the assumption of our lady, and the coronacion of our lady.' "	Stage V.
1550.	Davies, p. 262.	No play.	
1552.	Davies, p. 262.	No play.	
1554.	Davies, p. 263.	" 'Corpus Xpi playe shall (God willyng) be played this yere, and billets to be made forth as hath been accustomed, and that thoes pagiauntes tharof that were last forth shall be played ageyne as before tyme they were; and also that the xij and XXIIIjor, and all other occupacions accustomed to have torches shall have warnyng to prepare every man for their torches ageynst the sayd Corpus Xpi day.' "	Does the reference to torches in this entry, mean that the procession and the plays were on the same day?
1559.	Davies, p. 266.	No Corpus Christi play.	
1560.	Davies, p. 266.	No Corpus Christi play.	
1562.	Davies, p. 266.	Corpus Christi play given.	
1563.	Davies, p. 266.	Corpus Christi play given.	Stage V.
1564.	Davies, p. 266.	Observance of Corpus Christi play suspended.	
1565.	Davies, p. 266.	Observance of Corpus Christi play suspended.	

DOCUMENTS—Continued.

York.

Date	Document	Content	Interpretation
1566.	Davies, p. 266.	Observance of Corpus Christi play suspended.	
1567.	Davies, p. 266.	Corpus Christi play given.	
1568.	Davies, p. 266–9.	No Corpus Christi play.	Stage V.
1569.	Eng. Hist. Rev., IX, 301. Davies, p. 269.	Corpus Christi play acted on Whitsun Tuesday at twelve stations.	
1573.	Davies, p. 271.	No Corpus Christi play.	
1574.	Davies, p. 271.	No Corpus Christi play.	
1575–9.	Davies, p. 271.	No Corpus Christi play.	
1581.	Davies, p. 272.	Citizens ask for Corpus Christi plays.	Stage V.
1584.	Smith, *York Plays*, p. XXXV.	Pageant masters mentioned.	
1595.	Arch. Rev., I, 221.	Pageant masters mentioned.	
1611.	Smith, *York Plays*, p. XLI.	Pageant masters mentioned.	
?		Undated reference to support of pageants—Surtees 120: pp. 61, 62, 63, 64, 76, 79, 110, 113, 80, 86, 67, 196, 150.	Stage V.
?	Surtees, CXX, 155. Smith, *York Plays*, p. XXIV.	Saucemakers ask for help in supporting pageant of hanging of Judas.	Stage V.
?	Surtees, CXX, 166.	Controversy between mariners and fishers about paying for pageant.	Stage V.
?	Smith, *York Plays*, note, p. 125.	"Mynstrelles" to play play formerly given by Masons.	According to Miss Sellers in the English Historical Review, IX, 285, the date for this is 3 Eliz. (f. 40)
?	Davies, p. 247.	Crafts carried banners in the procession.	Stage II.
?	Davies, p. 250.	In reign of Henry VII—dispute between weavers and cordwainers as to place in the procession.	Stage I.
?	Davies, p. 245.	Corpus Christi Guild was bound "'to keep a solempne procession, the sacrament being in a shryne borne in the same through the city yerely the Fryday after Corpus Christi day.'"	

DOCUMENTS—Continued.

York.

Date, Document	Content	Interpretation
Early 15th Cent. A/y, p. 148.	Controversy between plasterers and tilers over payment for pageants for Corpus Christi.	Stage V.

Conclusion: The material for York presents some difficulties. After 1426, procession and pageants were on different days. Before 1426, the plays may, if the entry for 1426 has been correctly interpreted, have been acted during the procession. The course of the two through the city was the same. Both started at Holy Trinity (entries 1399, 1426) and stopped at St. Peter's and at St. Leonard's. Obviously more material, covering the period from 1325 to 1425, must be found to settle the matter.

The following material is too fragmentary to be conclusive. The first part of it concerns towns where only the procession is mentioned; the second concerns towns where only the plays are mentioned.

DOCUMENTS.

Date Document	Content	Interpretation
St. Michael's, *Bath.* 1465–6. Royal Historical Soc., VII, 328.	"Et sol. pro bajulacione vexilli iid. cruces ij d. torticiorum jd. ob. in die Corporis Xti, et diebus rogacionis, vd."	Procession was apparently purely an ecclesiastical one.
Cambridge. 1349–1538. 1. Davidson, p. 93.	1. Gild of Corpus Christi held a procession with pixies and shields until 1535.	
2. Wright, I, p. 154.	2. After the Gild of Corpus Christi of Cambridge ceased to exist, the College of Corpus Christi carried on the procession.	

DOCUMENTS—Continued.

Date	Document	Content	Interpretation
Cambridge.			
	3. Wright, 1, 147.	3. "The procession was led by the alderman of the gild, who was followed by the elders, those 'who had been aldermen, or were near the office, carrying enamelled silver shields in their hands. After the foundation of Corpus Christi College, the elders of the gild were followed in the procession by the master of the college, 'in a silk cope under a canopy, carrying the host in the pyx, or rich box of silver gilt,'—next came the vice-chancellor and members of the university, who were followed by the mayor and burgesses of the town."	
1519.	Stokes, p. 41.	Indulgences given for attending the public procession of the College on the Festival of Corpus Christi.	
Durham.			
	Surtees, CVII, 107. Cf. Same, p. 95. Longstaffe in Aeliana, II, 59.	There was a goodly p-sessio upo ye place grene on ye thursday after Trinite sonndaie in ye hono of Corp Christi daie ye wch was a pryncipall feast at that tyme. The baley of the towne [—] did calle ye occupac'ons that was inhabiters wth in ye towne eu'y occupatio in his degre to bring forthe ther Ban' wth all the lightes apteyninge to there seu'all Bann' & (90) to repaire to ye abbey church Doure eu'y banner to stand a Rowe (in ranke, Cos.) in his Degree from ye abbey church Dour to Wyndshole yett, on ye west syde of ye waye did all ye Bann' stand, and on ye easte syde of ye waye dyd all ye Torges [torches. Cos.] stand p'teyninge to ye sayd Bannares.	

DOCUMENTS—Continued.

Date	Document	Content	Interpretation
Durham.		Also there was a goodly shrine in Sacte Nicholas church, ordeyned to be caryed ye sayd daie in Procession —wherin was enclosed the holy sacramt of thaulter and was caryed ye said daie with iiij preistes vp to ye place grene & all ye hole prossessio of all ye churches in ye said towne goyng before ytt and when it was a litle space wth in Wyndshole yett yt dyd stand still, then was Sacte Cuthb:. Bann' browghte fourth wth two goodly faire crosses to meete yt and ye por & covent wth all ye whole companye of ye Quere all in there best copes dyd meet ye said shrine sytting on there kneys and praynge. The prior did sence yt (fetch it, Cos.) and then carynge yt forward into the abbey church ye por and covent wth all the quere following yt.—all ye Bann' of ye occupac'ons dyd followe ye said shrine into ye church goyng Rownde about Saincte Cuthb: fereture lyghtinge there Torches & burning all ye s'vice tyme. Then yt was caryed frome thence wth ye said p'ssessio of ye towne back againe to ye place from whence it came & all the Ban'p of ye occupac'ons following it, & setting yt againe in ye church."	From a roll of 1600. Although the crafts carried banners in the procession, pageants apparently never developed. Stage II. Cos. refers to Cosin's MS.
	Longstaffe, in Aeliana, N. S., II, 59.	This procession was continued until about 1770.	
Great Yarmouth. 1388–9.	Gross, I, 119, note.	Society of Corpus Christi maintained a light "'circa Corpus Christi annuatim in die Corporis Christi.'"	The crafts apparently were not concerned with the procession.
Leicester. 1349–1350.	Davidson, p. 93.	"The Gild of Corpus Christi of Leicester, which contributed to the most splendid procession in the city except that of St. George."	The crafts apparently did not have charge of the procession.

DOCUMENTS—Continued.

Date	Document	Content	Interpretation
Little Walsingham. 1541.	Archaelogical Proceedings, 1847, p. 147.	"'To ye berar of ye dragon at Corpus Christi mes and this Gild time, 4 *d.*'" (Gild of the Annunciation.)	In the thirty-second year of Henry VIII, Gild of St. Mary was united with Gild of St. Anne and St. George. Archaelog. Pro., 1847, p. 145. This explains the dragon. The procession was apparently in the hands of a religious gild, not of the crafts.
Reading. 1509.	Chambers, II, 392	Corpus Christi procession mentioned.	Plays were given at various times during the year, but no mention has been found of plays at Corpus Christi. Chambers, II, 392. L. T. Smith in York plays, p. LXVI mentions Corpus Christi plays of *Adam, Cayme.*
1512.	Chambers, II, 392	Corpus Christi procession mentioned.	
1539.	Chambers, II, 392	Corpus Christi procession mentioned.	
Kendal. 1575.	Chambers, II, 373	Corpus Christi play by crafte established in 1575. "pagiands off Corpus Xpi playe.'"	The date of the establishment of these plays is too late for them to have developed from the procession.
1586.	Chambers, II, 373	Alderman forbidden "to give permission for the acting of the play in any year without the consent of his brethren."	Stage V.
1612.	Chambers, II, 373	"Thomas Heywood says in 1612, that, 'to this day,' Kendall holds the privilege of its fairs and other charters by yearly stage plays."	
Early in reign of James	Chambers, II, 373	Weever in 1631 speaks of Corpus Play which he saw at Kendalle "'in the beginning of the raigne of King James.'"	
?	Chambers, II, 375.	"A Corpus Christi play was acted within the lifetime of Weever who was born 1576, and wrote 1631."	Stage V.
Louth. 1516.	Chambers, II, 383	"An inventory of documents in the rood-loft in 1516 includes the 'hole Regenall of Corpus Xii play.'	Stage V.
1558.	Chambers, II, 383	Corporation paid for a play 'in the markitstede on Corpus Xii day.'	From this reference the play seems to have been stationary.

DOCUMENTS—Continued.

Date	Document	Content	Interpretation
Preston.			
?	Chambers, II, 392	A Corpus Christi play was acted within the lifetime of Weever (born 1576, wrote 1631).	Stage V.
Sleaford.			
1477.	Davidson, p. 101.	"Gild of Holy Trinity (Three Kings of Cologne on Corpus Christi day, and play of the Ascension)."	"Probably tableaux with explanatory speeches. Possibly full plays By the crafts." Davidson, p. 101. Stage ?
Worcester.			
1467.	Chambers, II, 398	Corpus Christi play mentioned.	Stage V.
1559.	Chambers, II, 398	Corpus Christi play mentioned.	
1584.	Chambers, II, 398	Lease of "'vacant place where the pagantes do stand.'"	
Yarmouth.			
1473.	Chambers, II, 399	Play on Corpus Christi day mentioned.	Stage V.
1486.	Chambers, II, 399	Play on Corpus Christi day mentioned.	Stage V.

CONCLUSION.

My conclusions as to the relation between the Corpus Christi procession and the Corpus Christi play may be enumerated as follows:

I. In no case are all the stages to be found.

II. In Beverley, in Chester, in King's Lynn, and in Lincoln, stages I and V are represented. In Aberdeen stages I, II, V, VI; in Newcastle I, V, VI (?); in Norwich I, II, V; in York I, II, IV to 1426 (?), V; in Coventry I, V, VI, (?) are found.

III. Stage III is found apparently at Bury St. Edmunds, Bungay, and Hereford, but in each case the material is too fragmentary to be conclusive. The material for Dublin, I believe, refers to complete plays, processional in nature, but not given in the Corpus Christi procession.

IV. In many places there seem to have been plays and no procession, or a procession and no plays.

V. The length of time required to give the plays precludes any long connection with the procession.

VI. The date of composition of the plays in each town must be discovered before one can say definitely that the plays grew out of the procession.

VII. If one wishes to find the real relationship between the Corpus Christi procession and the Corpus Christi plays, he must find it *between 1311 and 1400.* After 1400, we have spoken drama in almost all the towns considered. Therefore all connection between plays and processions after 1400 must be *external,* merely hinting at the earlier internal relationship. We have as yet no material covering the period fully. The source material for the history of the plays in each town must be examined separately, and the conclusions obtained must be applied only to the individual places from which they were drawn.

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THE HEAT BUDGETS OF AMERICAN AND EUROPEAN LAKES.

EDWARD A. BIRGE.

Notes from the Laboratory of the Wisconsin Geological and Natural History Survey. VII.

This paper was suggested during the preparation of a report on the Finger lakes of New York, which was recently completed by Mr. C. Juday and myself, under the direction of the United States Bureau of Fisheries. (Birge and Juday, '14.) That part of the report which deals with the temperatures of these lakes was written by myself and its preparation led me to compare the results of our observations with those made on similar lakes in Europe.

In this paper an inland lake of the first class is defined as one whose size and depth are such as to permit the lake to acquire the maximum amount of heat possible under the weather conditions of the season. The lower limits for such lakes in the eastern and central United States seem to be about 10 km. of length with, at least, 2 km. of breadth; and 30 m. of mean depth, which means 50 m. or more of maximum depth. Such lakes must also lie under ordinary conditions of topography and altitude. Lakes whose conditions of climate or location are exceptional, such as those of alpine lakes at considerable elevations, cannot be compared directly with those in lower and more normal situations. (See Birge and Juday, '14, p. 561.)

The European lakes selected for comparison are, with one or two exceptions, all of the first class as regards size and depth. They lie at elevations rarely exceeding 500 m., so that the elevation can not play any considerable part in determining their heat cycle. These lakes are chiefly taken from lists used by

Forel and Halbfass in their discussion as to the effect of latitude on the heat budget. The mean temperatures employed are chiefly taken from two papers by Halbfass (Halbfass '05, '10). Without these compilations of numerous temperature observations from many authorities, gathered and computed with great care and labor, this paper could not have been written. In some cases I have checked Halbfass' results and usually have found that my computations closely agree with his. In some other cases, I have computed for myself the mean temperature of European lakes and such results are marked by a star in Table A.

No doubt more complete study will show that the heat budgets of the several lakes are influenced by elevation, surroundings, size of affluents and effluent, climate, cloudiness, latitude, and other conditions as well, but at present a direct and unmistakable effect of any one of these conditions can be pointed out in very few cases and it is best to consider the budgets in gross and without too much attention to particular circumstances.

Certain preliminary questions must be discussed before proceeding to the comparison of American and European lakes. These are: (A.) The definition of the heat budget. (B.) The unit which should be employed in stating it. (C.) The value of temperature observations, such as those from which the budgets have been computed.

A. Three things may be understood by the heat budget of a lake:

1. The amount of heat necessary to raise its water from 0° C. to the maximum temperature found in summer. This may be called the *gross* or *crude heat budget.*

2. The amount of heat necessary to raise its water from the minimum temperature of winter to the maximum summer temperature. This may be called the *annual heat budget.*

3. The amount of heat necessary to raise its water from 4°C. to the maximum summer temperature. This may be called, for reasons explained in the report on the Finger lakes, the *wind-distributed heat* or the *summer heat-income.* (See Birge and Juday, '14, p. 562.)

Of these three conceptions, the first is of least value, since it does not correspond to any facts in nature. No lake falls to 0° in winter, so that this temperature is not a starting point for any actual gains or a terminal point for losses. Still further;

the same conditions that limit the rise of temperature of a lake in summer limit also its fall in winter. Thus the gross heat budget may differ widely in lakes whose actual gain of heat per unit of surface are closely similar.

A single example of this may suffice. If the mean summer temperature, as given in Table A, of Owasco, Cayuga, and Seneca lakes is multiplied by the respective mean depths of the lakes, the products will be 39,800 cal., 50,500 cal., 68,300 cal., respectively—sums which represent the number of gram calories per sq. cm. of surface of the lake necessary to raise its water from 0° to the summer temperature. These sums differ very greatly; but if the mean temperature of the water in winter is multiplied by the mean depth the result shows how much heat was left in each lake at the winter minimum. These amounts are for Owasco lake 2,400 cal., for Cayuga, 12,200 cal., and for Seneca, 30,000 cal. When these sums, which are no part of any actual heat budget, are subtracted from the gross sums, the remainders (which represent the annual heat budget) are closely alike; 37,400 cal., 38,300 cal., and 38,300 cal., respectively. These numbers show that the indication of the gross heat budget is incorrect, and that each unit of surface of these lakes, in spite of wide differences in area and depth (see Table A.), is capable of taking up the same amount of heat from sun and sky; and this is a fact of no little interest.

The second conception, that of the annual heat budget, is a statement of facts of the first order of importance in the heat cycle of a lake. This method, therefore, which was used by Halbfass, in his comparisons of lakes, is by far the most fundamental of these three conceptions, and should always be used where the data are at hand.

The third conception, that of the wind-distributed heat, or summer heat-income, is one which serves much the same purpose as the second in cases to which it is applicable. It may be used in many cases where winter data are lacking, as is still true for many lakes. It applies only to the temperate lakes of Forel's classification. It has no significance for polar lakes, which do not rise above 4°; and in reference to tropical lakes it has the same difficulties that apply to the gross heat budget, as noted above. But for temperate lakes, the temperature of 4° constitutes, not a terminal point, but an important turning point in their annual temperature cycle, and most such lakes may fairly be compared with each other on the basis of their wind-distributed heat as well as on that of the annual heat budget. As shown by Table A, the conclusions to be drawn from the two types of budget are closely similar.

This statement holds for lakes which lie so far to the south that the temperature of 4° is reached early in the open season. If a lake lies far to the north it may not reach that temperature until a date so late as seriously to affect the remainder of its budget. This is clearly the case with Ladoga (See Table A, Fig. 1, and p. 45), in which 15,000 cal., or nearly one-half of its budget, were required to raise the water from the winter temperature to 4°.

This is in itself a large amount, although it is not so large as that demanded by Mjösen in 1901, and it is only slightly larger than that called for by Skaneateles lake in 1911. But the water of Mjösen reaches 4° early in June and the New York lakes reach that temperature early in May or even in April. Homén states ('02, p. 3) that Ladoga does not warm to 4° until the end of July. If this is the case, it is surprising that Ladoga accumulates so much heat above 4° as 18,000 cal. per sq. cm., since Homén also states that the temperature of the surface begins to fall by the end of August. In any case, it is clear that the summer heat-income of Wettern, Mjösen, and Ladoga is reduced by the late date at which the temperature of 4° is reached. It is also clear that the summer heat-income of these lakes cannot fairly be compared with that of lakes further south.

But the summer heat-income of lakes which reach 4° in April or early May in but little, if at all, affected by the amount of heat necessary to raise the water to 4°. The gains of heat may go on well into August, or even later, and so much heat is delivered to the lake which cannot be absorbed in any case, that in these lakes the summer heat-income is practically independent of the date when the temperature of 4° is reached, or of the amount of heat needed to warm the water to that point.

Thus, the size of each of the two members of the annual heat budget—that below and that above 4°—is independent of that of the other in many lakes. The variations in the lower part of the budget are due to winter conditions and are especially dependent on irregular accidents of weather rather than on the average conditions of the season. This part of the budget, therefore, introduces a considerable element of variation into the annual heat budget, which has little, or nothing, to do with the capacity of the lake for absorbing heat. This capacity may often be more exactly shown by the wind-distributed heat than by the annual heat budget.

The fact that winter losses and summer gains are measurably (although not wholly) independent of each other may also be seen in the budgets of tropical lakes, like Como and Geneva. Both lakes show greater variations in the winter than in the summer temperatures, and the annual heat budgets of both lakes are more variable than is common in lakes which regularly freeze during the winter.

B. The heat budget in any of its forms may be expressed in various ways, as follows:

1. The number of calories necessary to warm a column of water of unit base in the deepest part of the lake from the selected minimum (0°, 4°, winter minimum) to the summer temperature. This is the method followed by Forel.

2. The total sum of the calories necessary to warm in a similar way the whole mass of the water of the lake from the selected minimum to the summer temperature. This is the method employed by Halbfass in his paper of 1910.

3. The total number of calories necessary to warm in a similar way a column of water of unit base and a height equal to the mean depth of the lake. This method is used in this paper.

The first method was that employed by Forel ('95, p. 400, and '01, p. 41). It is well suited to very deep and very large bodies of water in which the annual temperature changes are confined to the surface strata, and whose area is so great that we may, without appreciable error, neglect the difference between the volume of the upper part and the lower part of the stratum in which these temperature changes take place. Such bodies of water are oceans and seas, and possibly also the very largest fresh water lakes. In the ordinary inland lake, however, neither of these conditions is met, and the method of stating the heat budget is correspondingly defective. It is also true, as stated by Forel, that it is not possible by this method to compare the heat budget of different lakes.

Forel at first took as his data the temperature found at the surface and at the successive 10 m. levels of the lake and added them. Since a column of water 1 cm. square and 10 m. high contains 1 liter, this sum gives the number of large calories necessary to raise a column of water, whose base is 1 sq. cm., and whose height is the maximum depth of the lake, from 0° to the temperature at the time of observation. This method was later modified by employing the mean temperature of each 10 m. section of the column of water instead of the temperature of the ends of the section. The unit of area was altered to the sq. dm., thus multiplying the number of calories in the result by 100 and escaping the necessity of using fractions of a calorie.

This method permits a study of the gain and loss of heat in any one lake, but it does not permit a comparison of different lakes.

If the method is applied to the New York lakes, the following results will be reached; which should be compared with those of Table A.

TABLE 1

ANNUAL HEAT BUDGETS OF NEW YORK LAKES, COMPUTED BY FOREL'S METHOD

Lake	Calories Winter, 1911	Calories Summer	Gain, cal.
Cayuga	30,100	(1910) 92,000 (1911) 86,400	61,900 56,300
Seneca	62,600	(1910) 120,400 (1911) 109,300	57,800 46,700
Owasco	3,500	(1910) 59,700 (1911) 53,900	56,200 50,400
*Green (Wis.)	16,200	(1910) 68,600 (1911) 67,100	52,400 50,900

The method can also be applied to measure the gains of heat above 4°, and the result for 1910 will be as follows:

TABLE 2

SUMMER HEAT-INCOME OF NEW YORK LAKES, COMPUTED BY FOREL'S METHOD

Lake	Calories, 1910	Lake	Calories, 1910
Canadice	25,000	Otisco	27,000
Canandaigua	40,100	Owasco	39,700
Cayuga	40,000	Seneca	44,500
*Green (Wis.)	39,800	Skaneateles	39,200

* This Wisconsin lake is smaller than the New York lakes, but of the same type. It is constantly used in comparison with them in Birge and Juday '14.

In these tables I have stated the results in small calories per sq. cm. of surface, in order to make them comparable with those given elsewhere in this paper. To agree with Forel's notation they should be divided by 10.

The figures are much higher for the deeper lakes than are those given by the other methods. They are correct so far as they go, but they may easily deceive. It is doubtless true—as the defenders of Forel's method replied to Halbfass—that these figures state correctly the amount of heat necessary to warm the given column of water in accordance with the observation. They do not show, however, how much of this heat came direct from sun and sky, and how much came in laterally from columns of water in the lake which are shorter, and therefore contain less heat. In other words, if the result for the column is carried over to the lake, the successive levels of the lake are treated as if each contained the same volume, and as a result the figures given in Table 1 show a much greater gain of heat than could possibly come directly from sun and sky, or from any other source outside of the lake. It is not probable that more than 70,000 gr. cal. per sq. cm. could be thus received by the surface of a lake during the five months, April to August, inclusive. It is quite beyond possibility that so many as 62,000 of these could be stored up in a lake. Thus, while a record of this sort may have a certain value for comparing results within a single lake at different times or in different years, it has little value for such a purpose as that for which it was used by Forel, viz., for comparing the relative gains of heat in lakes which lie in different latitudes.

In Table 2 the gains shown for the shallower lakes, Canadice and Otisco, are much lower, relatively to the deeper lakes, than would be shown by a comparison based on mean depth rather than maximum (see Birge and Juday '14). This is merely another illustration of the fact that different lakes can not be compared by this method. It deals with columns of water, not with lakes, and results reached by it can not be applied to lakes.

Not only may this method make the results larger than can be true for the lake, but the amounts of heat shown for the same lake in different years may differ more widely than they should do. In Seneca lake, for instance, the budget for 1910, as shown in Table 1, is nearly 24% greater than in 1911. This is true for the columns of water whose gains are shown, and in which the rise of temperature of a 10 m. section of the deep water involves as much heat as that of the water near the surface. Since, however, the volume of the lower strata of the lake is smaller than that of the upper, the amount of heat necessary to warm a given stratum of the deeper water of the lake is less than that needed to warm a corresponding stratum of the upper water, and when the volumes of the several strata are considered, the budget of 1910 was less than 11% greater than that of 1911, as is shown in Table A.

Forel's method, therefore, states the losses and gains of heat in a way which, while true for the column in which the temperatures were measured, may be obviously impossible when applied to the whole lake. Thus he gives for Ladoga ('01, p. 46) between certain dates a mean daily gain of 101 kg. cal. per sq. dm. and in a similar way for lake Enare a gain of 163 kg. cal. per day. These sums are equal to 1010 and 1630 gr. cal. per sq. cm., respectively. This amount of heat is far greater than can possibly be furnished to a lake by sun and sky. They are, as Brückner states "vollkommen unverständlich." The sun would very rarely deliver so much as 600 gr. cal. per sq. cm. per day for a month on a horizontal surface, and 1000 cal. are impossible. Thus it is plain that much of the apparent gain of heat in the column of water observed has come from other sources than sun and sky. As a matter of fact, it has been contributed by other parts of the lake whose column of water is shorter and whose gains are correspondingly smaller. If the gains of Ladoga are computed on the basis of the mean temperature and mean depth of the lake, they amount during the period named to about 160 gr. cal. per sq. cm. per day, instead of more than 1000 cal. The smaller figure is very moderate and wholly intelligible. The gains of lake Enare can not be thus computed since the mean depth of the lake is not known; but they are probably no greater than those of Ladoga and can not equal one-tenth of the amount computed by Forel. Obviously, the results of computations based on the maximum depth of lakes afford no basis for establishing laws concerning the relation of heat budget and latitude. Any conclusion on such a subject must be based on a knowledge of the heat gains of the average of the lake and not on those of a selected column of water.

Brückner ('09, p. 305) thinks that in spite of the objections of Wojeikoff and Halbfass, Forel's units are the best for the study of the physics of lakes, since they give exactly the facts of temperature for that part of the lake which covers the central plain ("der sogenannte Schweb"). We do not know exactly the temperature of the shallow parts of the lake, nor do we know exactly its volume, so that we cannot apply the needed corrections to this temperature. These considerations have a certain value, but, as already indicated, they are not of very much weight. The statement that Forel's units give a better idea of the physics of the lake may hold perhaps against Halbfass' method, but not against that of Wojeikoff, or that used in this paper. Indeed, as has already been indicated, if the student desires to correlate the heat cycle of the lake with that of the season, units of surface, depth, and temperature must be employed which will state the facts for the entire lake and not merely for a part of it.

The second method was introduced by Halbfass and was first applied by him in the papers to which reference has already been made. It has the fundamental advantage over Forel's method of basing itself on the mean temperature of the entire water of the lake and not upon that of part of it. But the use of the entire volume of the lake as a factor for computing total gains and losses of heat destroys for comparative purposes a large part of the advantage gained from the use of the mean depth in ascertaining the mean temperature of the water. This method employs a factor which varies with the individual lake, and thus restores in the result a difficulty similar to that which Forel's method suffers from his use of the maximum depth instead of the mean depth. A method by which the daily gains of loch Garry amount to 7 cal.; of loch Ness to 140; lake Geneva, 1430; and Wettern, 3400 cal. can give no really comparable results. Halbfass finds that in comparing lakes, he must select those of the same volume, and these he can roughly compare. This is true also under Forel's method if confined to lakes whose maximum depth is similar and in which the ratio $\frac{Dm}{Dmx}$ is nearly the same. But in both these methods the opportunity for comparison is greatly restricted.

Halbfass states gains and losses of heat in calories per day during the interval between the observations. This method reduces the number of calories to a comprehensible sum, but the expression is little more than a mathematical result under the circumstances to which it is applied. If temperatures had been taken daily, or even weekly, during the warming period of these lakes, it might be worth while to compute daily gains. But the case is far different. We must depend on a few—perhaps two—isolated observations in each year, one for winter and a second one for summer. Under such conditions a statement of "mean daily gains" has little meaning. There is really no significance in a "mean value" for the daily gain between (say) Feb. 5 and Sept. 7. The first month of this period may represent a daily loss; then may come daily gains increasing in amount and reaching a maximum in April or early May; then a slowing of gain leading to an almost stationary condition by late July and August, and passing probably into small losses in the later part of the period. Under such conditions, a statement of the mean daily gain or loss means little or nothing. A good illustration may be taken from lago di Como in 1904 (Halbfass, '10, p. 62). The winter temperatures were as follows: Jan. 26, 7.11°; Feb. 26, 7:00°; Mar. 28, 7.15°. The maximum recorded temperature of 8.96° was noted on Aug. 27. If the winter temperature in January only had been recorded, the mean daily gain would have been stated as about 160 cal. per day; if February had been taken, about 200 cal.; if March, about 220 cal. As a matter of fact, the temperature was substantially stationary during two months of the winter, and the mean daily gains stated for the season will vary nearly 40%, according to the winter date selected as the point of departure. The annual heat budget, however, is much the same whichever winter date is chosen.

The third method was first proposed, so far as I know, by Wojeikoff ('02, pp. 193–199) in a discussion of Forel's results. The same method was suggested by Wedderburn* ('10, p. 134). This method could not be applied widely until such a compilation of lake temperatures had been made as Halbfass' papers have furnished, and neither of the authors named has made any serious attempt to apply it.

The Wisconsin Geological and Natural History Survey has used this method in all of its work on Wisconsin lakes, which

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* It may be noted that the figures given for lake Geneva by Wedderburn (76,000 gr. cal. per sq. cm.) are certainly much too high. Loch Ness is assigned 34,000 cal., which is lower than my computations.

has been going on since 1898. It is the only method applicable under our circumstances, which involve a comparison between the heat budgets of lakes differing widely in form and area, but similarly situated as regards topographic and climatic conditions. It allows us to determine the influence of such factors as the area and depth of lakes on the amount of heat taken in by them. This unit, therefore, is employed throughout this paper.

If the heat budgets of lakes are to be widely studied, units must be selected, both for temperature and area, such that lakes may be compared in spite of great differences in area and depth. We have, therefore, computed the mean temperature of a lake on the basis of its mean depth. We derive the number of gram calories per square centimeter above zero, represented in this temperature, by multiplying it by the mean depth expressed in centimeters. We employ the gram calorie as the unit of heat and the square centimeter as the unit of area, because these units are employed by the meteorologist in stating the amount of heat received by the earth's surface from the sun.

C. The third preliminary question concerning the character of the observations from which our conclusions regarding lake temperatures are derived. The results shown in Table A are based on series of temperatures taken at the deepest part of the lake concerned. There is no difficulty in ascertaining with sufficient accuracy the mean temperature of the column of water in which such observations were taken. Nor is it difficult to compute from such observations the mean temperature of the water of the lake, provided a hydrographic survey of the lake has been made. But does such an expression give a correct idea of the mean temperature of the water? On this matter Wedderburn states ('07, p. 408): "It is in a far greater degree impossible to deduce the average temperature of a large loch from observations made in any one place." Halbfass also speaks ('13, p. 471) of "die Bedeutingslosigkeit einer Beobachtungsserie in vertikaler Richtung in einem vereinzeltem Punkt eines Sees".

If these statements are correct, then plainly such a paper as this, or those of Halbfass, are of no value, since they are based on just such observations as Wedderburn calls "futile" in the paper quoted, and which Halbfass thinks are "bedeutungslos". These are practically the only kind of observations now published for any lake. So far as I am aware, there is no lake whose temperature at all depths has been followed from day to day for a year, still less for a series of years. The Wisconsin Survey has done this for lake Mendota, but the results are still unpublished. The same is also to be said of the observations made by the station at Lunz. There is no lake the mean temperature of whose water is known in the same way as the mean temperature of the air is known for thousands of places all over the world.

In the paper on the Finger lakes, reasons are presented for believing that a single series of observations taken near the middle of a lake gives a fair account of the mean temperature of its water at the time of observation. (Birge and Juday '14, p. 556.) I shall not repeat these arguments at this place, but will add somewhat to them, mainly from the facts contained in Table A.

The mean temperatures of Green lake in nine seasons on dates varying from August 14 to September 8 show a total range of less than 1°, and a maximum range of about 12% in the wind-distributed heat. In those years in which observations were made on different dates, that one was selected which shows the highest result. I can not believe that so close an agreement would be present if the figures did not fairly show the mean temperature of the water. Certainly if the temperature of the water in different parts of the lake varies greatly, such a difference ought to cause a more considerable variation in results. If such observations are "futile", the futility ought to show itself by large variations in the temperatures indicated.

In the paper on the New York lakes, attention was directed to the close agreement between the mean temperature of lakes as deduced from observations made at the center and that derived from the mean temperature of several series of observations made along the axis of the lake. A maximum variation in the New York and Wisconsin lakes was found not exceeding 5%. The same result is reached if similar observations on European lakes are compared. Wedderburn ('07) gives several instances where temperatures in loch Ness were taken at Inverfarigaig at the center of the lake and at the same time near Ft. Augustus and Dores at its ends. The mean temperature of the lake, derived from the middle series and that derived from the three series, do not often differ by more than 0.1° C. This difference of temperature would correspond to a difference of about 1300 cal. in a budget of about 40,000 cal. Such a difference of about

3% is very far from the exactness expected in a laboratory experiment; but in the present state of our knowledge of lakes, a possible variation of 3% or 5%, or even a larger error, does not render an observation "futile" for purposes of general discussion.

The same general results as to the relation of observations at the center of the lake and those made simultaneously at the center and ends can be derived from the observations made by Wedderburn and Halbfass (Halbfass 10[a]) on the Madü-See in Pomerania.

In short, so far as I can learn from my own observations and from those of others, the statement made in the paper on the Finger lakes is correct: "It is fair to conclude that the mean temperature of the water of a lake of simple form may be derived from a single series of observations taken at or near the center of oscillation of the water." (Birge and Juday '14, p. 558.)

I am confident that this statement is true for American lakes in our latitudes up to 10 km.—15 km. of length. My experience of larger lakes is limited, but I believe that it holds true for them also. How far it is true for European lakes must be shown by observations made there. I am prepared to accept any conclusion which such studies may warrant, but I shall be surprised if observations made at the center of a lake are shown to be in general either "futile" or "bedeutungslos" as evidence of the mean temperature of the water of the lake.

I believe, therefore, that the numbers stated in Table A represent with general truthfulness the heat budgets of their respective lakes. The results obviously include several variable features, and they are, therefore, approximate and provisional. Yet they come from so many places and so many different years that they constitute a "random selection" of the facts. They so far agree with each other that certain general conclusions may be drawn which further study will doubtless modify, but which are not likely to be overthrown.

The results of Table A may be summarized as follows:

TABLE 3
ANNUAL HEAT BUDGETS OF EUROPEAN AND AMERICAN LAKES

Calories	European		American	
	Budgets	Lakes	Budgets	Lakes
Below 20,000	2	2	0	0
20,000-25,000	18	10	0	0
25,000-30,000	22	14	0	0
30,000-35,000	17	8	9	2
35,000-40,000	10	6	12	5
40,000-45,000	4	3	1	1
Above 45,000	3	3	0	0
	76	23	22	6

This table discloses the following facts:

1. The European heat budgets are on the whole smaller than the American. More than one-third of the whole number are below any American budget. Green lake (see Table A) has a larger average budget than any European lake except three of the giants—Geneva, Ness, and Mjösen. Owasco lake exceeds Green and is only slightly behind the other three. This is especially significant when we note that these two American lakes are shallower, both as regards maximum and mean depth, than any European lake recorded in Table A. and that their area is much below the average. Only five of the twenty-five European lakes are decidedly smaller than Owasco. Yet only three lakes besides those already named—lago di Como, Traun-See, Zuger See—have even single budgets that exceed Owasco's largest, or indeed, its mean budget.

It must also be noted that the small average size of the European budgets is due in great measure to the numerous mid-European lakes, whose budgets are in general very small. If only those lakes were considered which lie south of the Alps or north of latitude 55°, the difference in favor of America would be much less.

The larger amount of heat in the American lakes is due chiefly to their warmer epilimnion, as is shown elsewhere by a comparison of Cayuga lake and Würm-See.

There are also some very large budgets in the European series. Seven of them from five lakes exceed 40,000 cal., while only one American budget exceeds this sum, and that but slightly. In the paper on the Finger lakes (Birge and Juday, '14 p. 565) reasons were given for believing that the budget of Skaneateles lake exceeded 45,000 cal. in 1912, and no doubt this figure is reached and exceeded by other lakes, and a series covering a greater number of years would contain such budgets.

It is plain that budgets close to 50,000 cal. may be expected occasionally in both continents, but this seems to be near the possible maximum. In case of budgets that reach or exceed this figure, the data on which they are based should be very carefully scrutinized.

2. The range of the European budgets is much greater than that of the American. This might be expected, since the European lakes are more numerous than the American, they are distributed over a much wider area, and they lie in very different topographic and climatic situations. On the other hand, it is to be noted (a) that Green lake lies about 1000 km. west of the New York lakes and yet closely agrees with them; (b) that the variations in European lakes seem measurably independent of situation—so far as concerns single lakes—and (c) that single European lakes may show variations that cover nearly the whole range of the series. Lago di Como, with eleven budgets, has a range from 17,000 cal. to nearly 42,000 cal. and appears in five of the six classes of Table 3. Lake Geneva, with six budgets, appears in five classes and ranges from 22,000 cal. to nearly 46,000 cal. Zuger See, with four budgets, appears in four classes and ranges from 18,000 cal. to 44,000 cal. Certain lakes, like Traun-See, Mjösen, and perhaps lac du Bourget, have one budget much exceeding the others. Reasons are given elsewhere for believing that the great apparent size of Mjösen's budget of 1901 is at least partially deceptive; and very possibly a longer series of budgets would show a considerable range of variation in the other lakes, and fill in the gap between the small budgets and the large one. This is true of lac du Bourget, but not of

Traun-See, where the large budget of 1895 is in striking contrast with the ten others and must be regarded as exceptional. On the other hand, certain lakes with several budgets seem quite as regular as the American. Such are loch Ness, lago di Bolsena, Züricher See, Boden-See, and probably Würm-See. This regularity, where it exists, is the more noteworthy since the years from which budgets are reported cover a much wider range than is the case with American lakes.

The range of European budgets is so large that there is no use in calculating their mean. That of the American lakes is 36,000 cal., and the mean departure of each observation is less than 1,800 cal., or 5%. The maximum departure is +5,900 and —3,100, or a range of 25%. So far as the evidence goes, therefore, the heat budget of American lakes of the first class lying in the region of lat. 43° is in general much higher and more uniform than that of European lakes of similar character.

The amount of the summer heat-income in the temperate lakes is shown in the following table:

TABLE 4

SUMMER HEAT-INCOME OF EUROPEAN AND AMERICAN LAKES

Calories	European		American	
	Budgets	Lakes	Budgets	Lakes
Below 20,000	16	7	0	0
20,000–25,000	27	10	4	3
25,000–30,000	11	5	18	6
30,000–35,000	5	3	1	1
35,000–40,000	4	2	0	0
Above 40,000	1	1	0	0
	64	16	23	7

In this table the same facts are evident as in Table 3. More than 20% of the European budgets lie below any American; over 40% more lie in the class which contains less than 20% of the

American budgets; while 80% of the American budgets are in the upper region that contains only 40% of the European. It must be noted further that eleven budgets, or more than half of those found in Europe which exceed 25,000 cal., are from one lake—Traun-See, which is obviously exceptional in this particular. Some of the other exceptionally high budgets are discussed in the notes to Table A.

The uniformity of the American budgets is as noteworthy as their size. 80% of them lie between 25,000 and 30,000 cal. I do not suppose that a larger collection would show the same uniformity, but I believe that, on the whole, the American lakes will be closer to each other than are the European.

Forel's theory ('01) that the heat budget of northern lakes is greater than that of lakes farther south cannot be proved or disproved by the records of the European lakes, or by these with the addition of the American lakes. The budgets that exceed 40,000 cal. are as follows:

Como	41,800 cal.
Geneva	45,600, 40,200, 43,700 cal.
Zug	43,800 cal.
Traun	49,500 cal.
Mjösen	60,600 cal.

According to Halbfass' figures, loch Ness would have a budget of 43,000 cal. Of the American lakes, Skaneateles has one budget of 41,900 cal. and reason is given in our paper for believing that in this lake budgets as great as 45,000 cal. may be found. The same is doubtless true of other deep lakes of the Finger lake series. It seems certain that the budget of Mjösen is larger than the facts warrant. At any rate, these budgets show no decided preference for northern lakes and do not confirm Forel's theory. On the other hand, the average budgets of loch Ness and Mjösen (omitting the exceptional one) are somewhat, though but little, greater than those of Geneva, and possibly the average of many years is as great as 40,000 cal. Very probably a longer series would confirm this relation of superiority on the part of the northern lakes. But there is no good reason to attribute this difference to the northern latitude. There is more difference between Como and Geneva, separated by only 0° 21′ of latitude, than between Geneva and Mjösen, which lies over 14° further north. In view of the fact that Wettern and Ladoga show rather small annual heat budgets and that lochs Katrine, Lochy, and Morar, near neighbors of loch Ness, have budgets of no extraordinary size, it may well be questioned whether the large average budgets of Ness and Mjösen are not due to other causes than their northern situation.

So far as the data now before us can warrant a conclusion, it would be that the variations in the annual heat budgets of these lakes lie within the range due to the variations of the weather of the season. Thus lakes, whose latitude ranges from that of Mjösen (lat. 60°) to Geneva (lat. 46°) or Seneca (lat. 42°) may have identical budgets. We can not say that the mean budgets of the several lakes will not differ; indeed we may be sure that they will not be identical. But there is no reason to think that those of the northern lakes will have any great superiority or that any difference found will be due to the latitude. In a word, there is no evidence that the annual heat budget increases with latitude, within the limits of the zone between 40° and 60° north. Still further, the data from these lakes do not show that a temperate lake has a larger heat budget than a tropical lake of comparable area and depth.

The lakes of central Europe show on the whole smaller heat budgets than would be expected from American experience. The high winter temperature of these lakes which regularly freeze is noticeable, and this reduces the amount of that part of the annual heat budget which lies below 4°. Something of the same sort appears in the upper part of the budget also. While in the American lakes of the first class the wind-distributed heat will ordinarily exceed 25,000 cal., a decidedly lower figure would naturally be selected for those of central Europe.

An instructive comparison may be made between lake Cayuga and Würm-See which have closely similar mean and maximum depth. The comparison of their heat volumes shows that the main difference between these lakes lies in the upper 10 m. or 20 m. (Figs. 2–3). This region in Cayuga lake, down to 15 m., has a temperature substantially uniform and high, while in

Würm-See the temperature begins to decline almost from the surface. The amount of wind-distributed heat in the lower strata of Würm-See is as great as in those of Cayuga. But the European lake seems to lack the continuous sunshine, heat, and light winds of mid-summer which give the American lakes the peculiar character of their August temperature curves in the upper strata. This difference is apparently the characteristic one found when the temperatures of mid-European lakes are compared with those of lakes in our latitudes of America, and this is the usual cause of the lower heat budget, where such exists.

The August temperature conditions in the lakes of central Europe, in general, resemble those of American lakes in June. In the European lakes a relatively thick epilimnion is not formed in early and mid-summer as in ours, and a well-marked epilimnion is hardly developed in these lakes until the surface begins to cool. From this fact comes the statement, not uncommon in European writers on lakes, that the thermocline is a phenomenon which develops during the cooling period of a lake. No student of American lakes would make such a statement, since the epilimnion is fully formed in July, even in a large lake, while in smaller lakes it may be well developed in June or even in May.

In Fig. 1 the number of gram calories in the annual heat budget of each lake is indicated by the length of the line assigned to it. The position of the line on the figure indicates the character of the lake as tropical or temperate, and its position in the class to which it belongs. The line marked "0" indicates the temperature of 4°. In the case of the temperate lakes the lake lines cross the zero line and the length of that part of the line to the left of zero indicates the number of calories per square centimeter which its water loses below 4°; or in other words the number of calories per square centimeter of its surface required to raise its water from the winter temperature to 4°. That part of the line to the right of the zero line indicates the number of calories per square centimeter necessary to raise its water from 4° to the summer temperature, or the summer heat-income. In the case of the tropical lakes the left end of the line is placed

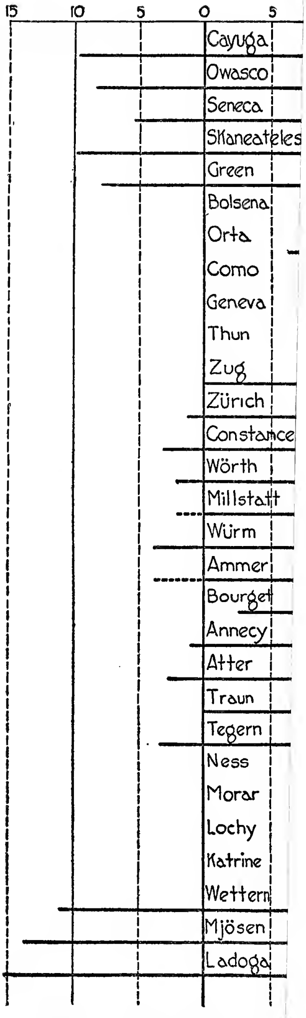

Fig. 1. This diagram show
of the lake. Each division of th
The place of the line on the diag
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cluding in the budgets of that la
In general, where there are
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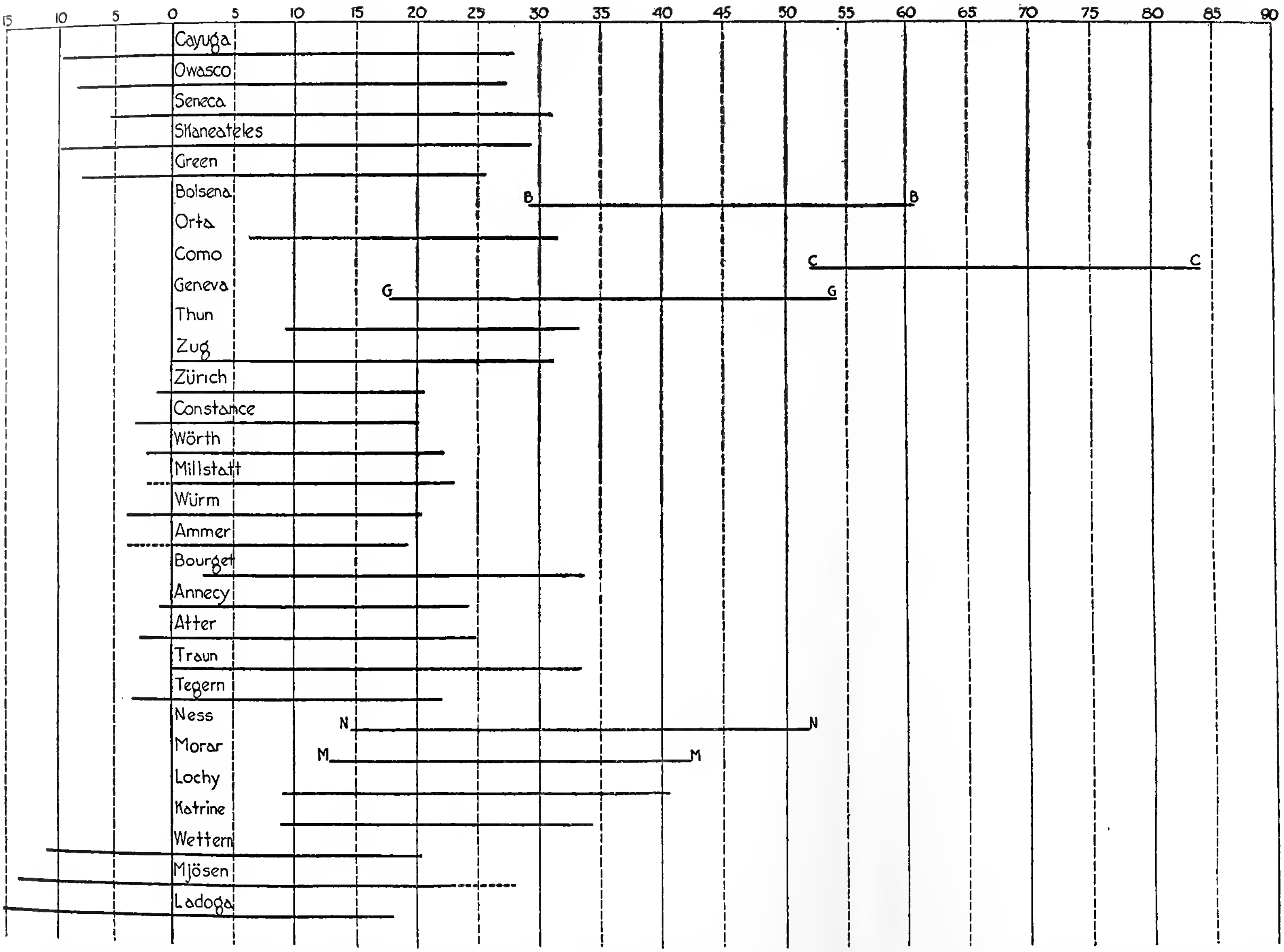

Fig. 1. This diagram shows the annual heat budgets of American and European lakes, expressed in gram calories per square centimeter of the surface of the lake. Each division of the diagram indicates 5,000 cal. per sq. cm. The length of the line for any lake indicates the amount of its annual heat budget. The place of the line on the diagram indicates the position of the lake as tropical or temperate. The zero line is drawn at the temperature of 4°. The budget of a tropical lake is shown by a line wholly to the right of the zero line. That of a polar lake, if one were present, would lie wholly to the left of the same line; that of a temperate lake crosses the line.

The broken line extending the budget lines of Millstätter See and Ammer-See to the left indicates the supposed loss of heat below 4° in these lakes during winter. No winter observations have been made on them. The broken line extending the budget line of Mjösen to the right shows the effect of including in the budgets of that lake the budget of 1901. See p. 43.

In general, where there are more than two budgets for a lake, the mean is taken. In those tropical lakes for which several winter temperatures are recorded, the mean is taken for the starting point of the lake line.

at the point indicating the number of calories necessary to raise its water from 4° to the winter temperature. It represents in some sense the permanent stock of heat in the lake above 4°.

The diagram shows, for instance, that Cayuga lake is a temperate lake; that its annual heat budget is about 37,000 gram calories per square centimeter of the surface of the lake; that of these calories more than 9,000 lie below 4°; that about 28,000 cal. constitute the summer heat-income. It shows that lago di Bolsena is a tropical lake; that at its winter temperature the water still contains wind-distributed heat to the amount of about 29,000 gram calories per square centimeter of its surface; and that its annual heat budget is about 32,000 calories.

The temperature of 4° is taken as the starting point for four reasons:

1. The lakes all approach within a measurable distance of 4° in the autumn or winter of each year.

2. If 0° C. were taken as the starting point the distances from zero line to beginning of lake line would vary greatly. In Owasco lake in 1911 only about 2,400 cal. would remain in the lake; in Mjösen some 60,000 cal.; in Seneca nearly 64,000 cal.; in Como 126,000 cal. Yet Mjösen had lost below 4° some 15,000 cal. per sq. cm. and Owasco only about 6,200, and it is well worth while to bring out this fact.

3. Losses of heat below 4° and gains of heat up that point are subject to very different laws from those at a higher temperature and should be treated separately.

4. The principal reason, however, for placing the zero line at the temperature of 4° is the fact that in this way the place of the lake in Forel's classification can be shown in the diagram, as well as its position in the class to which it belongs.

The diagram shows the main facts of Table A in a way which conspicuously strikes the eye. Among them I should name:

1. The small heat budget of a series of mid-European lakes from Thuner See to Traun-See, and their general uniformity in spite of differences of size, depth, situation, etc. The differences (with two possible exceptions—the largest of Zuger See and Traun-See) all seem to be within the possible range of annual variation of any one of the lakes.

2. The small loss of heat below 4° in these lakes as compared with north European or American lakes. In the case of Millstätter See and Ammer See, where no winter temperatures are recorded, this item is conjectural and is so indicated by the use of dotted lines.

3. The uniformity of the American lakes, both as to losses below 4° and gains above it. The diagram also brings out a possible error in the observations on Seneca lake. We can give no reason why that lake, which does not freeze, should not have lost as many calories per sq. cm. in 1911 as the other lakes. Cayuga lake, which also does not usually freeze, shows substantially the same losses as Owasco and Skaneateles, whose temperatures were taken through the ice. Very likely, therefore, the water at the point of observation in Seneca lake showed a temperature somewhat above the mean of the lake. It is quite possible, however, that the observation correctly shows the facts.

4. The three northern lakes of the continent of Europe show a budget of similar character in spite of great differences in area and depth. In each case there is a very large loss below 4°, so large as to affect the possible gains above 4°. The gains of Ladoga and Wettern seem to be closely similar, although more evidence is needed on this point, either to confirm or refute it.

5. The very large and deep lakes, Mjösen, Ness, Geneva, and Como, have on the whole decidedly larger budgets than the lakes which are their neighbors. This inference is weakened by the small budget found for Thuner See in 1908–09, but this may be due to local reasons, or a larger series of observations may show that its great mean depth—50% greater than any of its neighbors—gives it a certain advantage over them, when the average of a considerable number of series is taken.

6. The large budgets of lago di Bolsena show (a the favoring effect of area on budget; (b) a high winter temperature is not incompatible with large gains of heat.

7. The fact that the Scottish lakes are tropical in spite of their high latitude is a testimony to the general mildness of the winter. It is surprising that summer gains of heat are so large. Continuous sunshine, however, is by no means especially favorable for large gains of heat, as it warms the surface too rapidly.

8. No clear relation can be discovered between latitude and size of heat budget.

9. More important than any of these specific results is the conclusion that, by the method employed, it is possible to express in similar units and to compare the heat budgets of lakes which differ widely in area, depth, etc.; that, even from the imperfect temperature records now available, important generalizations can be made as to the heat cycle of these lakes; and that it is plainthatmoreabundant data will enable us to correct and to extend these generalizations.

Figure 2 and figure 3 are diagrams showing the quantity of heat in the several 10 m. strata of Cayuga lake and Würm-See. Each of the larger divisions of the network represents 2° horizontally and 5 m. vertically. The horizontal lines marked 10, 20, etc. are so placed as to show the "reduced thickness" of the several 10-m. strata; that is, the thickness of each 10-m. stratum if its area were extended to that of the surface of the lake and if its sides were vertical. This thickness is computed by dividing the volume of the stratum by the area of the surface of the lake.

The area in the diagram, bounded by the lines representing winter and summer temperature and by any two of the 10-m. boundary lines is proportional to the amount of heat delivered to that stratum from the surface of the lake. Each of the larger squares included in such a quadrilateral represents 1000 gr. cal. per sq. cm. of the surface of the lake delivered to the stratum and each small square represents 40 such calories. The area bounded by any two of the 10-m. lines, the temperature line of 4°, and the temperature curve gives the summer heat-income of the stratum in question.

On the dates selected for summer temperatures the temperature of the two lakes at the surface was almost identical. In Cayuga lake the temperature of the epilimnion falls very slowly and has declined less than a degree at 15 m. In Würm-See the temperature declines rapidly below 5 m. and at 15 m. is more than 10° below that of Cayuga. This lake was also warmer at depths immediately below 15 m., the difference falling to 0.4° at 40 m. At 50 m., 60 m., 70 m., and 80 m. Würm-See was

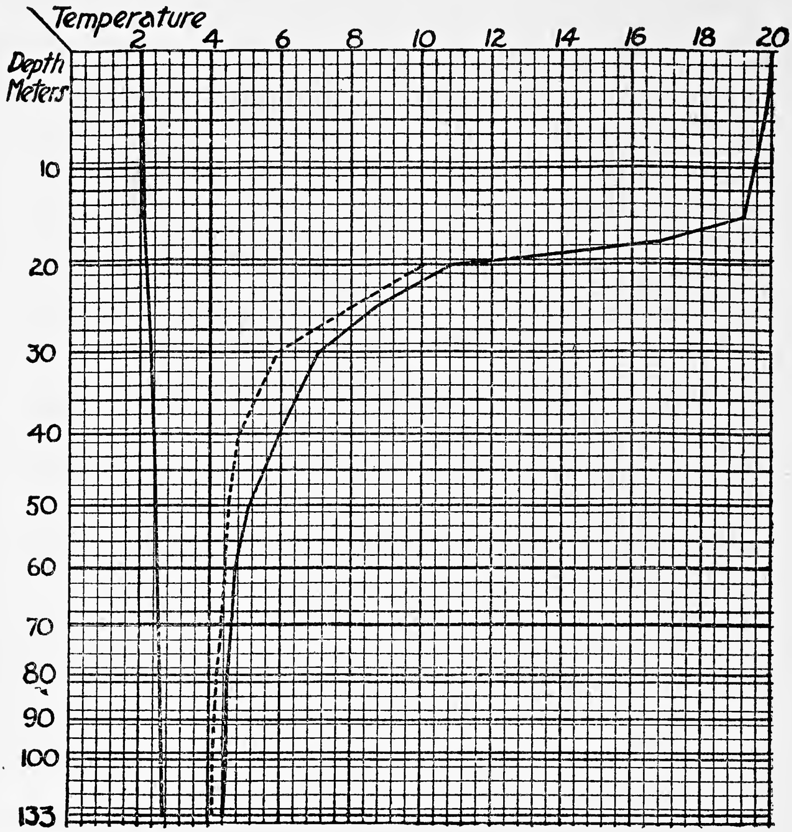

Fig. 2.—Diagram to show the heat income of Cayuga lake. The date of the winter temperature was Feb. 13, 1911; those of the summer temperatures were Aug. 11–12, 1910 (full line) and Sept. 2, 1911 (dotted line).

warmer, and at 100 m. and below the lakes were of the same temperature. The heat budget of the lakes differs widely, being about 44% greater (11,400 cal.) in Cayuga lake than in Würm-See. But little of this difference comes in the upper 10 m. where the greater reduced thickness of Würm-See compensates for its lower temperature. Nearly 70% of the difference comes in the strata between 10 m. and 40 m., where the temperature of Würm-See is much below that of Cayuga; and a great part of the remainder comes in the bottom strata whose volume is much smaller in Würm-See, corresponding to its smaller maximum depth.

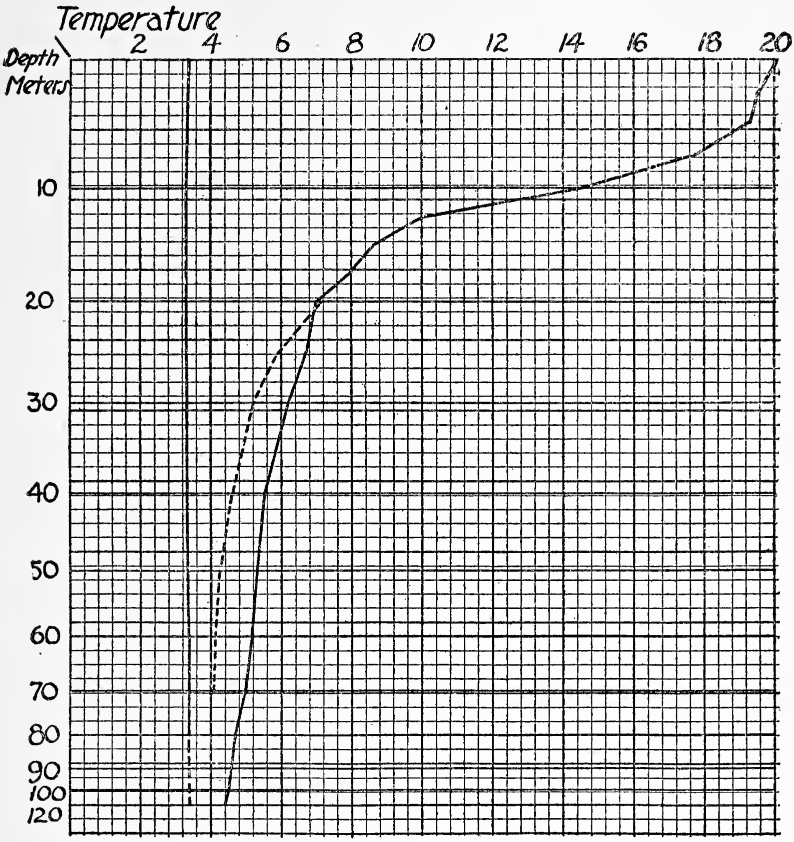

Fig. 3.—Diagram to show the heat income of Würm-See. The date of the winter temperature was March 16, 1894; those of the summer temperatures were Aug. 21, 1897 (full line) and Oct. 10, 1895 (dotted line). There is only one winter series from this lake. The summer record of 1897 was chosen because on that date the surface closely agreed in temperature with that of Cayuga lake in 1910. The record of the lower water for Oct. 10, 1895 (a date too late for maximum temperatures in the upper water) was added because the deeper water shows a low temperature, substantially like that of Cayuga in 1911.

A large part of the difference between the budgets is due to the higher winter temperature of Würm-See, 3.30° as compared with 2.23° in Cayuga. This difference on a mean depth of 54 m. would make the annual heat budget of Cayuga about 5,800 cal. larger (more than one-half the difference in the budgets) than that of Würm-See. In the wind-distributed heat therefore, the two lakes differ much less than in the annual heat budget.

The summer heat-income of Cayuga lake is about 5,600 cal. larger than that of Würm-See. Over 80% of this difference lies in the stratum between 10 m. and 20 m. and therefore in the thermocline region. The following zones down to 40 m. more than make up the rest, while the wind-distributed heat in Würm-See between 40 m. and 80 m. is greater than in Cayuga lake at the same depths. (See Table 5.)

These facts show (1). That the agents for distributing heat are substantially as effective in Würm-See as in Cayuga lake; and that the smaller heat budget of the European lake is not to be attributed to its smaller size or to less efficient agents for the distribution of heat. (2). That the gains of heat in early spring are not essentially different in the two lakes. (3). That the possibilities of gaining heat become less for the European lake as the season advances. (4). That the main difference in the temperature and in gain of heat lies in the epilimnion and the thermocline.

TABLE 5

COMPARISON OF CAYUGA LAKE AND WURM-SEE

Depth, meters	Reduced thickness, meters		Temperature, Cayuga			Temperature, Würm			Annual Heat Budget		Summer Heat-Income	
	Cayuga	Würm	1910, VIII, 11	1911, II, 13	1911, IX, 2	1897, VIII, 21	1894, III, 16	1895, X, 10	Cayuga	Würm	Cayuga	Würm
0–10	8.34	9.23	19.6	2.00	....	18.2	3.35	....	14,680	13,710	13,010	13,110
10–20	6.88	8.07	17.1	2.10	....	9.60	3.30	....	10,320	5,080	9,010	4,500
20–30	6.28	7.20	8.80	2.20	8.00	6.60	3.30	6.10	4,140	2,380	3,010	1,870
30–40	5.75	6.29	6.45	2.30	5.35	5.85	3.30	4.90	2,390	1,600	1,410	1,160
40–50	5.11	5.50	5.50	2.40	4.65	5.40	3.30	4.42	1,580	1,100	770	770
50–60	4.52	4.70	4.90	2.45	4.45	5.22	3.35	4.18	1,110	900	410	570
60–70	4.05	3.91	4.65	2.50	4.35	5.08	3.40	4.07	870	660	260	430
70–80	3.62	3.10	4.55	2.55	4.25	4.85	3.40	4.00	720	450	200	260
80–100	5.88	3.94	4.50	2.60	4.15	4.60	(3.40)	4.00	940	470	290	230
100–bot.	4-09	0.92	4.45	2.70	4.10	4.45	(3.40)	4.00	720	100	180	40
									37,470	26,050	28,550	22,940

TABLE A—HEAT BUDGETS OF AMERICAN

No.	Lake	Situation	Lat.	Elevation Meters	Length Kilometers	Bre'th Kilometers	Area Hectares	Depth. Maximum Meters	Depth. Mean Meters
1	Canandaigua....	United States... New York	42° 45′	209	24.9	2.4	4,226	84	38.8
2	Cayuga..........	United States... New York	42° 30′	116	61.4	3.5	17,212	133	54.5
3	Keuka............	United States... New York	42° 30′	216	31.6	3.3	4,697	56	30.5
4	Owasco..........	United States... New York	42° 50′	217	17.9	2.1	2,669	54	29.3
5	Seneca............	United States... New York	42° 30′	135	56.6	5.2	17,541	188	88.6
6	Skaneateles	United States... New York	42° 50′	264	24.2	2.4	3,591	90	43.5
7	Green............	United States... Wisconsin	43° 48′	275	11.9	3.2	2,973	72	33.1
8	Bolsena..........	Italy.............	42° 36′	305	13.0	11.0	11,453	146	78
9	Orta..............	Italy.............	45° 45′	290	13.7	2.4	1,820	143	71
10	Bourget..........	France..........	45° 44′	231	17.7	3.5	4,462	145	81

AND EUROPEAN LAKES.

Winter Temperature, Tm^W		Summer Temperature, Tm^S.		Tm^S-Tm^W		Annual Heat Budget $Dm\ (Tm^S-Tm^W)$	Wind-distributed Heat. $Dm\ (Tm^S-4.)$		No.
Date	Value	Date	Value	Year.	Value	Calories	Year	Calories	
....	....	1910 VIII 20	11.07	....	....	....	10	27,500	1
....	....	1911 IX 4	9.99	....	....	....	11	22,900	
1911 II 13	2.23	1910 VIII 11	9.26	10—11	7.03	38,300	10	28,600	2
....	....	1911 IX 2	8.94	11—11	6.71	36,600	11	26,900	
....	....	1910 VIII 18	12.17	....	....	....	......	24,900	3
....	....	1911 IX 5	11.48	....	....	....	......	22,800	
1911 II 5	0.83	1910 VIII 13	13.59	10—11	12.76	37,400	10	28,100	4
1912 III 1	1.49	1911 IX 3	12.86	11—11	12.03	35,200	11	26,000	
		1912 IX 13	13.93	11—12	11.37	33,300	12	29,100	
				12—12	12.44	36,400			
					Mean	35,600	Mean	27,700	
1911 II 10	3.39	1910 VIII 5	7.71	10—11	4.32	38,300	10	32,900	5
....	....	1911 IX 1	7.35	11—11	3.96	35,100	11	29,700	
1911 II 11	1.10	1910 VIII 14	10.10	10—11	9.00	39,200	10	26,600	6
1912 III 7	2.39	1911 IX 3	10.74	11—11	9.64	41,900	11	29,300	
				11—12	8.35	36,300			
					Mean	39,100			
1901 I 25	0.85	1900 IX 8	11.6	00—01	10.75	35,600	00	25,200	7
1906 II 15	1.31	1905 VIII 20	12.0	05—06	10.69	35,400	05	26,500	
1911 III 2	2.13	1906 VIII 14	12.3	06—06	10.99	36,400	06	27,500	
1912 III 18	1.74	1908 IX 3	11.3	10—11	9.67	32,000	08	24,200	
1913 III 10	1.86	1909 VIII 20	12.1	11—11	9.77	32,300	09	26,800	
1914 III 8	1.70	1910 IX 1	11.8	11—12	10.16	33,600	10	26,000	
		1911 VIII 17	11.9	12—12	10.26	34,000	11	25,900	
		1912 VIII 15	12.0	12—13	10.14	33,500	12	26,500	
		1913 VIII 21	12.2	13—13	10.34	34,200	13	27,100	
		1914 VIII 12	12.0	13—14	10.50	32,800	14	26,500	
				14—14	10.30	34,100			
					Mean	34,000	Mean	26,200	
1903 II 24	7.89	1897 VII 29	11.84	03—03	4.23	33,000			8
1904 III 14	8.32	1900 VII 20	8.95	03—04	3.80	29,600			
1906 II 25	7.00	1903 VIII 28	12.12	04—04	3.90	30,400			
		1904 VII 18	12.22	06—06	4.28	33,400			
		1906 VIII 25	11.28		Mean	31,600			
1895 II 16	4.89	1894 IX 9	8.47	94—95	3.58	25,400			9
1894 III 4	4.95	1894 VIII 10	8.27	94—94	3.32	26,900		34,600	10
1895 II 26	3.70			94—95	4.57	37,000			

TABLE A—HEAT BUDGETS OF AMERICAN

No.	Lake.	Situation.	Lat.	Elevation Meters	Length Kilometers	Bre'th Kilometers	Area Hectares	Depth.	
								Maximum Meters	Mean Meters
11	Annecy..........	France..........	45° 51′	447	16.8	3.5	2,704	65	41
12	Como............	Italy............	46° 0′	198	48.3	4.0	14,591	410	185
13	Geneva..........	France.......... Switzerland	46° 21′	372	72.3	13.8	58,246	310	154
14	Thun,............	Switzerland......	46° 43′	560	18.0	3.0	4,792	217	135
15	Zug..............	Switzerland......	47° 10′	417	13.5	4.5	3,831	190	84
16	Zürich...........	Switzerland	47° 30′	409	40.0	4.0	8,778	143	44
17	Constance .... Bodensee	Switzerland	47° 38′	395	67.0	13.0	83,850	252	90

AND EUROPEAN LAKES—Continued.

Winter Temperature, Tm^w. Date.	Winter Temperature, Tm^w. Value.	Summer Temperature, Tm^s. Date.	Summer Temperature, Tm^s. Value.	$Tm^s - Tm^w$. Year.	$Tm^s - Tm^w$. Value.	Annual Heat Budget Dm ($Tm^s - Tm_w$) Calories.	Wind-distributed Heat. Dm (Tm^s-4.) Year	Wind-distributed Heat. Dm (Tm^s-4.) Calories.	No
1890 II 28	*3.37	1890 VII 29	*9.86	90—90	6.49	26,600	90	24,000	11
1894 II 14	*4.85	1891 VII 10	*9.35	93—94	5.81	23,800	91	21,900	
1895 II 27	*3.02	1893 VIII 18	*10.66	....	....	....	93	27,300	
						....	Mean	24,400	
1895 II 12	6.00	1394 VIII 12	8.26	94—95	2.26	41,800			12
				95—95	2.04	37,700			
1899 II 8	7.15	1895 VIII 21	8.04	98—99	0.92	17,000			
1900 III 25	6.96	1898 VIII 2	8.07	99—99	1.66	30,700			
1901 III 7	6.86	1899 IX 26	8.81	99—00	1.80	34,200			
1903 II 26	6.91	1900 IX 10	8.64	00—00	1.64	31,000			
1904 II 25	7.00	1902 X 30	8.68	00—01	1.78	32,900			
		1903 VIII 24	8.50	02—03	1.77	32,700			
		1904 VIII 27	8.96	03—03	1.59	29,400			
				03—04	1.50	27,800			
				04—04	1.96	36,300			
				Mean	....	32,000			
		1879 VIII 20	7.80						13
1880 II 26	4.84	1880 IX 8	7.21	79—80	2.96	45,600			
1883 II 26	5.92	1884 IX 23	8.00	80—90	2.37	36,500			
		1885 VIII 18	7.94						
1884 III 15	6.01	1889 IX 19	6.57	84—84	1.99	30,600			
1891 II 21	4.07	1900 VIII 16	7.27						
1892 I 16	4.65	1906 IX 14	8.06	00—00	1.43	22,000			
1894 I 24	4.33	....	....	06—06	2.61	40,200			
1900 IV 12	5.84	....	....	06—07	2.84	43,700			
1906 IV 2	5.45	....	....	Mean	2.37	36,600			
1907 III 22	5.23								
1848 III 28	4.65	1848 IX 6	6.48	48—48	1.83	24,700			14
1849 II 3	4.72	1880 VIII 5	6.57	48—49	1.76	23,800			
1097 I 8	4.50	1906 VIII 21	7.50	06—07	2.90	24,400	08	38,900	15
1908 II 22	4.00	1907 IX 2	6.67	07—07	2.17	18,200			
1909 III 6	3.41	1908 VIII 10	8.63	08—08	4.63	38,900			
				08—09	5.22	43,800			
					Mean	31,300			
1897 I 5		1897 VII 20	9.33	97—97	5.38	23,700	97	23,500	16
1906 II 25	3.88	1906 VII 1	8.53	06—06	4.65	20,500	06	19,900	
1907 III 16	3.34	1907 VII 13	7.93	06—07	5.19	22,800	07	17,300	
				07—07	4.59	20,200			
					Mean	21,800		20,200	
		1870 IX 1	7.12				70	28.100	17
		1880 VIII ?	6.73				80	24.600	
1890 II 28	3.49	1889 VIII 28	5 81	89—90	2.32	20,960	89	16.300	
1891 II 7	3.57	1890 ? ?	6.20	90—90	2.71	24,400	90	19,800	
1907 II 28	3.91	1907 X 10	6.58	90—91	2.63	23,700	07	23,200	
				07—07	2.67	24,000			
					Mean	23,200		22,400	

TABLE A—HEAT BUDGETS OF AMERICAN

No.	Lake	Situation	Lat.	Elevation Meters	Length Kilometers	Bre'th Kilometers	Area Hectares	Depth Maximum Meters	Depth Mean Meters
18	Wörth..........	Austria..........	46° 35′	432	16.0	1.6	1,944	85	43
19	Millstatt.........	Austria..........	46° 50′	580	11.4	1.9	1,325	141	86
20	Hallstatt........	Austria..........	47° 33′	494	8.2	2.1	858	125	65
21	Würm...........	Germany	47° 47′	584	20.0	4.3	5,710	123	54
22	Ammer..........	Germany	48° 0	533	15.8	5.2	4,700	82	33
23	Atter............	Austria..........	47° 47′	465	20.0	3.3	4,672	171	84

AND EUROPEAN LAKES—Continued.

Winter Temperature, Tm^{W}.		Summer Temperature, Tm^{S}.		Tm^{S}—Tm^{W}		Annual Heat Budget	Wind-distributed Heat. Dm (Tm^{S}-4.)		No.
Date.	Value	Date.	Value.	Year.	Value.	Dm (Tm^{S}—Tm^{W}) Calories.	Year	Calories.	
1890 II 2	3.71	1889 VIII 9	9.79	89—90	6.08	26,100	89	24,900	18
1891 III 6	3.34	1890 VIII 15	9.15	90—90	5.44	23,400	90	22,100	
1892 II 7	3.45	1891 VIII 25	8.60	91—91	5.36	23,000	91	19,800	
1893 II 11	3.57	1892 VIII 21	9.58	92—91	6.24	26,800	92	24,000	
1894 II 4	3.49	....	....	92—92	6.13	26,400			
				92—93	6.01	25,800			
					Mean	25,300	Mean	22,700	
		1890 VIII 20	6.48				90	21,300	19
		1893 IX 6	6.82				93	24,300	
		1894 VIII 22	6.75				94	23,600	
							Mean	23,000	
1849 II 2	3.48	1848 VI 9	7.74	48—49	4.26	27,700	48	24,300	20
1897 II 23	4.43	1849 VIII 31	7.80	49—49	4.32	28,100	49	24,700	
		1868 IX 26	7.58	96—97	3.69	24,000	68	23,300	
		1869 IX 23	7.25		Mean	26,600	69	21,100	
		1891 VIII 28	7.59				91	23,300	
		1896 VIII 22	8.12				96	26,800	
							Mean	23,900	
1894 III 16	3.30	1881 IX 12	7.71	93—94	4.08	22,000	81	20,000	21
		1893 IX 21	7.37	94—94	4.74	25,600	93	18,200	
		1894 VIII 11	8.03				94	21,800	
		1895 IX 8	*8.16				95	22,500	
		1896 VIII 3	7.28				96	17,900	
		1897 VIII 21	*8.32				97	23,300	
		1900 VII 27	*8.17				00	22,500	
							Mean	20,700	
		1903 IX 28	*8.97				03	18,900	22
		1881 IX 13	*9.14				81	19,500	
1875 IV 11	3.68	1848 IX 2	7.22	74—75	3.28	27,600	48	27,000	23
		1868 X 5	7.12				68	26,200	
		1870 IX 23	6.09				70	17,600	
		1873 X 6	*6.83				73	23,800	
		1874 IX 21	*6.96				74	24,900	
		1878 X 6	*6.25				78	18,900	
		1891 IX 18	6.88				91	24,200	
		1894 IX 26	*7.42				94	28,700	
		1895 VIII 31	7.74				95	31,400	
							Mean	24,900	

TABLE A—HEAT BUDGETS OF AMERICAN

No.	Lake	Situation	Lat.	Elevation Meters	Length Kilometers	Bre'th Kilometers	Area Hectares	Depth Maximum Meters	Depth Mean Meters
24	Gmundener...... Traun............	Austria..........	47° 50′	422	13.0	3.0	2,565	197	90
25	Arend............	Germany.........	52° 34′	21	3.2	2.8	554	49	29
26	Tegern...........	Germany.........	47° 42′	725	6.0	2.0	921	71	43
27	Ness.............	Scotland.........	57° 15′	16	39.0	3.2	5,670	238	133
28	Morar............	Scotland.........	56° 51′	9	18.8	2.5	2,670	310	87
29	Lochy............	Scotland....	56° 59′	28	15.7	2.0	2,530	162	70
30	Katrine	Scotland.........	56° 15′	111	12.9	1.6	12,400	151	61
31	Vettern...	Sweden	57° 57′	88	119	32	189,800	119	39
32	Mjösen..........	Norway..........	60° 22′	121	99	16	35,940	452	187
33	Ladoga	Russia	61° 20′	5	210	120	1815,000	223	56

AND EUROPEAN LAKES—Continued.

Winter Temperature, Tm^w.		Summer Temperature, Tm^s.		$Tm^s—Tm^w$		Annual Heat Budget	Wind distributed Heat. $Dm(Tm^s-4)$		No.
Date	Value	Date	Value	Year	Value	$Dm(Tm^s—Tm^w)$ Calories	Year	Calories	
1895 III 7	2.66	1848 VIII 30	7.23	95—95	5.50	49,500	48	29,100	24
1906 II 25	4.04	1868 X 10	8.25				68	38,000	
1907 II 12	4.27	1869 X 1	*8.10	06—06	3.26	29,300	69	36,900	
		1870 X 26	*7.00				70	27,000	
		1873 X 5	*7.54	06—07	3.03	27,300	73	31,900	
		1874 IX 25	*7.72				74	33,500	
		1878 X 7	*7.49	07—07	3.03	27,300	78	31,400	
							91	28,200	
		1991 VIII 29	7.13		Mean	33,400	95	37,400	
		1895 IX 6	8.16				06	29,700	
		1906 VIII 22	*7.30				07	29,700	
		1907 VII 19	*7.30						
							Mean	32,100	
		1895 VIII 19	11.83				95	22,700	
1897 II 7	1.52	1896 VIII 5	10.89	96—97	9.37	27,200	96	20,000	25
1906 II ?	3.2	1905 VIII 1	9.1	05—06	5.90	25,400	05	21,900	26
1887	5.10	1887 IX 8	*7.65	87—87	2.55	33,900			27
1904	5.10	1903 VIII 17	*8.00	03—04	2.90	38,600			
		1904 IX 15	*8.05	04—04	2.95	39,200			
					Mean	37,200			
1887	5.50	1887 IX 3	*8.74	87—87	3.24	28,200			28
1903 III 26	5.45	1902 VII 3	*8.70	02—03	3.25	28,300			
		1903 X 23	*9.10	03—03	3.65	31,800			
					Mean	29,400			
1887	5.30	1887 IX 7	*9.80	87—87	4.50	31,500			29
1900 III 10	4.44	1900 IX 6	*8.67	00—00	4.23	25,800			30
1899 III 23	2.20	1899 VII 26	7.71	99—99	5.51	21,500	{ 99	14,500	31
							{ 00	15,700	
1900 III 24	0.33	1900 IX 2	8.09	00—00	7.76	30,300	03	18,300	
1903 II 15	0.90	1903 VIII 11	9.80	03—03	8.70	33,900	06	16,400	
1906 II 26	1.47	1906 X 7	9.41	06—06	7.94	31,000			
1907 II 24	0.81	....	... .	06—07	8.60	33,500			
					Mean	32,000		16,200	
1899 I 7	*3.25	1899 IX 14	*5.18	99—99	1.93	36,100	99	22,100	32
1900 III 11	*3.25	1900 IX 10	*5.24	99—00	1.93	36,100	00	23,300	
(1901 III 9	*3.27)	1901 VIII 7	*6.41	00—00	1.99	37,300	01	45,100	
1901 IV 17	*3.17	....	....	00—01	2.07	38,700			
				01—01	3.24	60,600			
				Mean	{	†41,800		†30,200	
						37,000		22,700	
1900 IV 25	1.26	1900 X 17	7.20	00—00	5.94	33,300	00	18,000	33

† Including 01—01.

Notes on Table A.

All temperatures for American lakes have been computed by myself; the same is true for those European temperatures which are marked with a star. The data for Ammer See come from Geistbeck '85 and Ule '06; those for Tegern-See come from Breu, '06. All other data are from Halbfass' papers of '05 and '10.

In the table annual gains of heat are shown by subtracting the winter temperature from that of the summer following, and are indicated thus in the table, '95–'95. Losses of heat are shown by subtracting the winter temperature from that of the preceding summer, and are shown thus, '95–'96. Both changes in temperature are taken as the basis for computing the annual heat budget. Thus observations in two successive summers and the intervening winter afford a basis for stating two budgets. This is the method followed by Halbfass in the papers to which reference has been made. The formula is Dm (Tm^s–Tm^w), in which Dm represents the mean depth in centimeters; Tm^s, summer mean temperature; Tm^w, winter mean temperature.

The summer heat-income is computed by subtracting 4° from the summer mean temperature and multiplying the remainder by the mean depth expressed in centimeters. The formula is Dm (Tm^s–4).

The variations in the number of calories reported for a single lake in the table are caused by a variety of conditions. Chief among them is the variation in the temperature of the water in the different years. Exceptional seasons cause exceptional budgets. This may be well illustrated by the temperature of Traun-See in 1895. The winter temperature that year was only 2.66°, or nearly 1.5° below the other winter temperatures reported. The summer temperature was high, though not so far above the average as to be obviously exceptional, but the combination caused a budget of nearly 50,000 cal., undoubtedly very close to the possible maximum. Probably 6,000 cal.—9,000 cal. of this total are due to the exceptionally low winter temperature, which is considerably below that reported for any other European lake of approximately equal depth. A second case may be that of Mjösen in the summer of 1901, but this will be discussed further on.

Secondly, the temperature of the particular period in which the observations were made may cause minor variations in the record. This period may have been cold, warm, or average, and the temperature of the water will vary accordingly. In Wettern, the mean temperature for July 11, 1900, was 7.39° (Halbfass, '10, p. 62); Aug. 12, 6.48°; Sept. 2, 8.09°. There is thus indicated a loss of 3,000 cal. between the first and the second observation and a gain of 6,300 cal. between the second and third. The middle of August normally gives a reading close to the maximum, but on this occasion the series taken on August 12 would have given an annual budget nearly 20% smaller than it really was.

Thirdly, the mean temperature derived from the observations may not fairly represent the mean temperature of the lake. This general question has been discussed elsewhere in this paper. There are but few cases which seem to be of this character. The most conspicuous is that of Mjösen in 1901, which is discussed later in these notes.

Nos. 1–7.—The mean depths of the American lakes are given to tenths of a meter, not to indicate greater accuracy of the survey, but that the number of calories may agree with those stated in the paper of Birge and Juday ('14) to which reference has been made. This paper should be consulted for a more complete account of the heat budgets of these lakes.

In the case of Green lake, the summer temperatures are given to the first decimal place only. This has been my usual custom with the temperatures of Wisconsin lakes, and it did not seem worth while to recompute the temperatures of Green lake, since in the case of any lake the value of the figure in the second decimal place is wholly uncertain. In all summers when the lake was visited more than once, the highest reading has been taken.

The uniformity of the heat budget is noteworthy, especially in comparison with the irregularities of most European lakes. The maximum departures of the annual heat budget from the mean are about 7% in either direction; those of the summer heat-income are less. This last fact means that there is more difference between the loss of heat below 4° than in the gain of heat above this point. That part of the heat budget which lies below 4° ranged from 6200 cal. in 1911 to 10,500 cal. in 1901. It should be noted, however, that the higher temperature was taken in March and would be above the minimum temperature of the lake, which would come at the time of freezing. Green lake seems to gain about 25 cal. per sq. cm. of surface per day during the ice--period. The temperature at the time of freezing might have been as much as 0.5° (1600 cal.) colder than the record in March. But there is no doubt that the lake might freeze at any of the temperatures indicated.

No. 8. Lago di Bolsena.—The large heat-budgets of this southern lake are noteworthy, especially in comparison with those of the lakes north of the Alps. It will be observed that the low temperature record of 1900 can not be used as basis for a budget. It no doubt indicates a very small heat budget for that year. A longer series from Bolsena should show variations like those of Como and Geneva.

No. 9. Lago d'Orta.—No definite conclusion can be based on the single budget from this lake, although it is probable that Como, like Geneva, has a larger budget than its smaller and shallower neighbors.

No. 10. Lac du Bourget.—Very probably the temperature of March 4, 1894 is above the minimum for that year, and probably the temperature in Feb. 1895 was below the minimum of the preceding year. This is clearly the case in the neighboring lac d'Annecy. This lake and lac d'Annecy lie near the southwestern end of lake Geneva. They evidently are lakes which are near the dividing line between Forel's classes of tropical and temperate lakes.

No. 11. Lac d'Annecy.—This lake was measured from Delebecque's large map and its volume was computed from my measurements. The result for total volume was substantially the same as that given by Delebecque. The maximum depth should be stated as 64.7 m. since this is the maximum depth in the central plain of the lake. The depth 81.6 m. is found in the Boubioz, a large sub-aqueous spring, but so small that it has no appreciable effect on the total volume of the lake. From these measurements of volume, I have computed the temperature. The result are higher for the years 1890 and 1891 than are those of Halbfass. They are substantially the same in 1893.

No. 12. Lago di Como.—The mean temperatures given by Halbfass in his two papers differ considerably. I have used the later figures, since they have probably been revised and corrected. These changes throw some doubt on the temperature for the summer of 1898, which is given only in the paper of 1905, and which is lower than in any other year except one. The changes made in the figures for 1894 and 1895 alter these from the smallest budgets to the largest. The excess is due to the exceptionally low winter temperature for 1895, which is nearly 1.0° (18,500 cal.) below the mean of the other five years recorded. I have not included in the record the figures given in Halbfass' paper of 1905 for the years 1887 and 1889, since these should probably be increased like the numbers for later years. If the budget '98–'99 is omitted, the mean of the total number recorded will be increased 1500 cal. It will probably not be far wrong if the mean for Como is reckoned at 32,000 cal.—33,000 cal., and, therefore, very close to that recorded for lago di Bolsena.

The exceptionally small budget '98–'99 depends on the combination of an unusually low summer temperature, and an unusually high winter temperature. The difference as measured in degrees is not very great, but since the mean depth of the lake is nearly 200 meters, the difference in the heat budget is very large.

No. 13. Lake Geneva.—For this lake, north of the Alps, we have a considerable number of budgets as we have for lake Como south of the Alps. The maximum budget is above that of Como; the minimum is higher than Como's minimum, and the average is also considerably greater. These lakes lie in substantially the same latitude. Lake Geneva is the larger which would tend to increase its budget, but it is also the shallower, which, if this fact has any influence in lakes so deep, would be in the opposite direction. The main cause for the greater heat budget of lake Geneva seems to lie in the colder winter, which reduces the temperature to a point where the heat can be more rapidly absorbed than is possible in Como.

It may be noted that the minimum budget for lake Geneva is less than half the maximum, a ratio not very different from that found in Como.

During the summer the Rhone carries an enormous volume of cool water into lake Geneva and an equally large volume of warm water is drawn off from its surface. It does not appear, however, that this fact operates to reduce the annual heat budget of the lake. The annual heat budget of lake Geneva is higher than that of any other lake in the table except loch Ness and Mjösen. It is substantially the same as that for Mjösen if the single exceptionally high budget of Mjösen is omitted.

It will be noted that the winter temperature for 1891, 1892, and 1894 are lower than any others recorded. Since the temperatures of 1892 and 1894 are in January, they are probably above the minimum for those years. If we had summer temperatures corresponding to these winter observations the budgets would almost certainly have been unusually high, probably over 40,000 cal., and would have raised the average for the lake.

Nos. 14–25.—There are twelve lakes in the table which belong to the region of the Alps north of Italy and east of lake Geneva. To these may be added lac d'Annecy and lac du Bourget. These lakes furnish thirty-five budgets of which seventeen lie below 25,000 cal., fourteen are between 25,000 and 30,000 cal., and four are exceptionally high. Omitting the four high budgets the mean of the remaining thirty-one would be below 25,000 cal. If all were included it would be somewhat below 27,000 cal. The Vierwaldstätter See has been omitted from the table on account of its complex form, and there are no annual heat budgets recorded for Ammer See or Millstätter See, since winter temperatures are lacking. But it is evident that were the budgets from these three lakes added to the list the mean would not be essentially altered.

These lakes range in mean depth from 38 m. to 135 m., although only one exceeds 90 m. The area varies more than one hundredfold, from 822 ha. to 83,850 ha. The elevation above the sea ranges from slightly below 400 m. to 725 m. The lakes lie within the Alps in Switzerland, Austria, and France and on the north side of the Alps in Germany and Austria. The general uniformity and small amount of the annual heat budgets in lakes so numerous, so various, and so widely distributed is remarkable. Equally noteworthy are the exceptionally high budgets which appear in two of the lakes, and the large average budgets which appear in Traun-See.

The conclusion seems warranted that lakes in the region of the Alps, and north of Italy, have annual budgets in the region of 25,000–27,000 calories, and that lake Geneva with its mean of 36,500 cal. is far above the average for such lakes, though not beyond the amount which other lakes may reach in exceptional years.

Nos. 14–17.—These Swiss lakes lie to the east of lake Geneva. Their annual heat budgets are all low and are all fairly uniform with the exception of Zuger See. This lake shows an exceptional range in its budgets due to a considerable variation both in the winter and in the summer temperatures. I cannot assign any reason for this wide variation, nor can I state why its budgets should rise so much higher than those recorded for the other lakes.

If the temperatures of Thuner See are derived from Halbfass' table of 1910, they will be found somewhat lower than those given, which are from his paper of 1905. The annual heat budgets, however, are but little altered by the change.

The summer temperatures for Züricher See were all taken in July and may be lower than the maximum.

Nos. 18–20.—These lakes continue in Austria, at a considerable distance, the series of Swiss lakes which ends with Constance and they lie substantially in the same latitude. Their heat budgets are also approximately the same.

It will be remembered that there is a doubt both as to the area and depth of Hallstätter See. I have taken the smaller figures. If the larger are taken, the budgets will be increased by about 15%.

No. 19. Millstätter See.—Halbfass (13a, p. 312) compares the temperatures of Gmundener (Traun–) See and Millstätter See as taken on Aug. 20, 1913. He finds the latter lake "erheblich wärmer" than Traun-See, and thinks that the difference may perhaps be due to the east-west direction of the long axis of Millstätter See, while that of Traun-See lies north and south.

The case is, however, not so simple as this suggestion would imply, and Halbfass has not called attention to the peculiarity which seems to be the most important one. The upper strata of Millstätter See are indeed warmer than those of Traun-See, as are those of Atter-See (see below). But from a depth of 15 m. down Traun-See is the warmer and this is the more significant difference between the temperatures of these lakes.

The observations on Aug. 20, 1913, did not extend to such depths that the mean temperatures of the lakes can be computed; but there can be no doubt that on this occasion, as on all others in late summer, Traun-See contained much more heat than Millstätter See. The latter lake agrees in general with the other lakes of its class in the Alps, both as to the amount and the distribution of its heat. Traun-See is the exceptional case among these lakes. The interesting question is not so much how the upper 10 m.—15 m. of Millstätter See come to be warmer than those of Traun-See; for in this respect Millstätter See agrees with Atter-See, whose long axis, it may be remarked, extends from north to south. We should like rather to know how the deeper strata of Gmundener See are able to gain such an exceptionally large amount of heat and how its water accumulates a total quantity of heat so much in excess of that gained by other and neighboring lakes of comparable area and depth.

Nos. 21–25.—These are illustrations of lakes from the north slope of the Alps. Würm-See and Ammer See lie close together in the neighborhood of Munich and are in the relatively low foot hills. Atter-See and Traun- or Gmundener See lie further east in Austria and are in mountain valleys, though their surface is not so high above the sea as that of the first two named. Their mean depth is also much greater. These lakes have heat budgets entirely comparable both in amount and variation with those of the group of Swiss lakes which lies on the other side of the Alps.

I have included Ammer See whose dimensions are somewhat less than those of Würm-See in order to show how nearly identical in these lakes was the summer heat-income in 1881, the only year when we can compare them. Geistbeck ('85 p. 30) places Würm-See among the cold lakes and Ammer See among the warm, but the mean temperatures taken on successive days on the two lakes agree within 5% and that of Ammer See is the lower. I have no doubt that further observations will show the same general result since Ammer See has a smaller mean depth than Würm-See.

Nos. 23, 24. Atter-See, Traun-See.—The large budgets of Traun-See, both annual and summer, are especially noticeable. Two of the three winter temperatures reported are above 4.0° and one is much below that temperature, making a great difference in the annual heat budgets. I have, however, computed the wind-distributed heat in each year in which there is a late summer or early autumn record, relying on Müllner's ('99 p. 3) statement that the water of all these lakes goes annually below 4.0°. I have made a similar computation for the neighboring Atter-See. The eleven records for Traun-See are both high and uniform. Traun-See indeed has a much greater amount of wind-distributed heat than any other central European temperate lake which is recorded. A comparison of the records of Atter-

See and Traun-See show that in every case where temperatures were observed on closely adjacent days, Atter-See had a higher temperature at the surface and in the upper strata; but at a depth of 50 schuh (15.8 m.) or more, Traun-See was the warmer. It is plain that the larger amount of heat in Traun-See depends not on the reception of a greater supply at the surface, but on the greater efficiency of the means of distributing it to the deeper water, or on the larger supply brought to the middle and lower strata of the lake by the river Traun. The temperature records for both lakes come from Müllner '99.

No. 25. Tegern-See.—The budget of this lake is very probably affected by its altitude which is greater that that of any other lake in the table. The temperatures for this lake come from Breu '06.

No. 26. Arend-See.—This small lake is placed in the table to show how close the heat budget of a small European lake comes to that of the larger lakes. An American lake of the same size would show a smaller heat budget. This lake is not used in the general discussion of results.

Nos. 27, 28. Loch Ness, Loch Morar.—I have included budgets from four of the Scotch lakes. All of them have been computed by myself from data derived from Murray and Wedderburn. I have taken as the winter temperature of loch Ness Wedderburn's estimate of 41.2° F., 5.10° C. The temperature given in the table for Sept. 15, 1904 is the mean of five series taken near the center of the lake on such dates in mid-September as to make the mean date fall about Sept. 15.

The winter temperature for loch Morar in 1887 is taken from the bottom temperature found on April 29th of that year. The lowest temperature recorded is 41.8° F. Halbfass' figures ('05 p. 227) for Sept. 9, 1887 are undoubtedly too high.

It is difficult to understand why the budgets of loch Morar should be so much smaller than those of loch Ness. The maximum depth of loch Morar is greater, and both its mean depth and area are ample to insure a maximum heat budget. No such difference appears in the budgets of the mid-European or the American lakes. It is possible, that, since loch Morar is situated nearer the sea, the greater cloudiness prevents the temperature of the water from falling as low in winter as does that of loch Ness. If, however, the budgets were to be as great as those of loch Ness, the summer temperatures must also be decidedly higher than those recorded. It is possible that this is also due to lack of sunshine. In any case, it seems plain that the large budgets of loch Ness are exceptional among the Scottish lakes in much the same way that those of lake Geneva are among those of the Swiss lakes.

The figures given by Halbfass ('10, p. 61) would assign a budget to loch Ness for 1904 amounting to 43,000 cal. This is somewhat higher than my computation shows, but is a wholly possible budget and one that loch Ness has doubtless reached.

No. 30. Loch Katrine.—Halbfass ('05, p. 226–227) gives the temperature of loch Katrine on Mar. 10, 1900 as 5.52°; Sept. 6, 1900, 11.16°. These figures he repeats ('10, p. 62). If, however, the mean temperature of the water is derived from table 1 of his paper of 1910, by dividing the total heat by the volume of the lake, the temperature for Mar. 10 would be 4.42°; Sept. 6, 8.91°. I have computed mean temperatures for loch Katrine, basing my results for volume on the areas given by Murray; and my result for Sept. 9, 1812 is 8.00°, the same as that of Halbfass ('05, p. 227); so that my hydrographic data seem to be the same as his. The temperature records which I have used for computing the temperatures of 1900 come from Forel ('01, p. 37) and I cannot see that my results are in error. In the temperature records, no reading is given at 25 m., and the temperature depends somewhat on the reading inserted there, but the mean temperature could not go above 8.8° in any case. The mean depth of the lake as given by Murray (Vol. II, p. 3) is 199 ft. which equals 61 m., not 62 m. as stated by Halbfass. If the temperature derived from table 1 in Halbfass' paper of 1910 are employed, the heat budget would be 27,400 cal., substantially the same as mine.

No. 31. Wettern.—The annual heat budgets of this lake are by no means extraordinarily large. The wind-distributed heat is small, owing evidently to the low temperature of the water in winter and the relatively late date at which the lake reaches the temperature of 4°. This lake lends no support to Forel's doctrine of increasing budgets with increasing latitude. The comment on Fig. 1 (p. 21) should be consulted for a discussion of the low summer heat-income of this lake and the next two.

No. 32. Mjösen.—The average heat budget of this lake is large, though if the budget for 1901 be omitted it is smaller than that of loch Ness. There is no question but that the temperatures of the lake for 1901 are correctly recorded and computed but it does not seem possible that they give correctly the mean temperature of the lake.

Professor Halbfass has kindly informed me of certain corrections to be made in his computations for Mjösen. The volume of the lake should be 67.1 cu. km. not 69.1 cu. km. as given in Halbfass' paper of 1910. This change reduces the mean depth $\left(\frac{A}{V}\right)$ to 186.7 m. instead of 192.9 m. I have computed again the temperatures of the lake on this basis and find them somewhat different from those assigned by Halbfass. A source of difference besides the change in volume is in the method of computation. If in the 0–10 m. level, for instance, readings are given at 0 m., 5 m., 10 m. Halbfass takes that at 5 m. as representing the mean of the stratum; while I use the mean of the three readings.

The changes in computation make no essential difference except in the summer of 1901. There can be no doubt that the water south of the island of Helgöen was unusually warm during that season. The mean temperatures are as follows: Apl. 17, 3.17°; May 26, 3.62°; July 1, 5.27°; Aug. 7, 6.41°. The following table shows the gains computed for a mean depth of 187 m.

TABLE 5

GAIN OF HEAT, MJÖSEN

Date	Gain of temperature	Calories	Calories per day
Apl. 17–May 26	0.45°	8,400	215
May 26–July 1	1.65°	30,900	858
July 1–Aug. 7	1.14°	21,300	576
		60,600	497

A gain of nearly 61,000 cal. in 122 days is quite impossible. So great a gain as nearly 600 cal. per day during July seems beyond the credible and a gain of over 850 cal. during June is very far above anything that can be accepted. The gains during April and May are normal.

The observations were made south of the island Helgöen, which is about 4.0 km. long and lies some 50 km. from the north end of the lake and 34 km. from the south end.* The 400 m. contour extends within about 16 km. (less than one-fifth of the total length of the lake) of the south end of the lake. The observations of 1901 did not extend below 400 m. If they were made at the south end of the deep water the apparently high mean temperature may be due in part to a temperature seiche and in part to transport of warm water from the very large north part of the lake and its accumulation in the south part. If the readings were taken near Helgöen the latter cause must have predominated. This was probably the chief factor in any case, since the lake has a form somewhat resembling a funnel with the broad part toward the north and with a narrow extension toward the south. This form would make it easy for a north wind to force large masses of the warm water into the south end of the lake. In any case, the high temperature of the surface water shows that the budget for 1901 was unusually large.

In 1901 the temperature taken through the ice on Apl. 17 (3.17°) was lower than that taken on Mch. 9 (3.27°). In the latter case the readings were taken only to a depth of 320 m. and probably in shallower water than the April series, which extends to 420 m. Very likely the mean of 3.22° would fairly represent the winter temperature. The water in April was colder at all depths than in March and of course there was no opportunity for the water to cool under the ice if the lake was completely frozen.

The readings of the other years for Mjösen are wholly reasonable: but it should be noted that the observations taken on Sept. 14, 1899 extend only to 200 m. and must be conjecturally supplied for the deeper water.

There are no other series from any lake included in Table A which give clearly incorrect indications regarding the heat budget. Mjösen is a lake in which such errors would be more likely to occur than in any other lake included in the list. The shape of the lake in general, the situation of the island, the eccentric position of the deep water, the great length of the relatively shallow north arm, all combine to make it anything but a lake of simple form in which a single series of temperature observations taken at the center may be fairly expected to indicate the mean temperature of the lake. (See map, Huitfeld-Kaas '05.)

* The measurements are taken from the small map in Huitfeld-Kaas '05.

No. 133. Ladoga.—The summer temperature given for this lake is very probably too high. It comes from a series taken on October 17. The mean temperature derived from a series on Sept. 7 of the same year was 0.85° lower, indicating a gain of nearly 4800 cal. per sq. cm. between these two dates. Such a gain at this time of the year is quite impossible, since it must be as much as half the total radiation from sun and sky. Either the earlier series is too low or the later one is too high and no important conclusions should be based on this single budget.

It may very likely be true, as stated by Halbfass ('10, p. 63), that "die Wärmezunahme des Ladogasees übertrifft die des Würmsees ganz ausserordentlich"; but the maximum budget for Würm-See is 25,600 cal., while if the September temperature is taken for Ladoga, its budget would be 28,500. This difference or that shown in the table hardly warrants so strong an assertion. Very probably, however, the mean of a series of years would show that the budget of Ladoga is the greater, since its temperature is very low both in winter and summer. A large part of its gain of heat, therefore, lies below 4° and just above that point, and at these temperatures, a larger percentage of incident heat will be stored than at higher temperatures, like those of Würm-See in summer.

In concluding these notes on Table A, I will add that I have given care to secure accuracy in the numerical data which it presents. I can not even hope that complete accuracy has been attained; when I follow the work of others in this field I find what seem to me to be errors and I can not doubt that similar mistakes occur in my data. But I believe that such errors as may be found to exist in the table—as in the other cases to which I referred—are not numerous or serious enough to invalidate or weaken the general results announced in the paper.

I ought to conclude this paper, as I began it, with acknowledgment of indebtedness to the work of Professor Halbfass ('05, '10) from which so much of my data has been derived.

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LIMNOLOGICAL STUDIES ON SOME LAKES IN CENTRAL AMERICA.

BY C. JUDAY.

During the month of February, 1910, four lakes situated in Central America were visited for the purpose of making some limnological observations on them. The purpose of these investigations was to make such studies on these tropical lakes as had been made on a considerable number of lakes in the temperate zone so that comparisons could be made with respect to dissolved gases and net plankton content. It was the purpose, also, to obtain data concerning the vertical circulation of the waters of deep lakes possessing such markedly tropical characteristics. A permanent stratification, resulting in a permanent stagnation of the lower strata of water, doubtless, would have presented some interesting biological problems, but such conditions do not obtain in any of these lakes. Lastly, since they are situated in volcanic regions information was desired with respect to the effect of such phenomena on the dissolved gases as well as on the other substances held in solution by their waters.

These four lakes lie on the Pacific slope of Central America. Two of them are situated in the republic of Guatemala and are known as lakes Amatitlan and Atitlan. The other two, lakes Ilopango and Coatepeque, are situated in the republic of Salvador.

Climate.

These four lakes lie far within the tropics, being located near the middle of the north tropical zone. Lake Atitlan is the most northerly and it is less than 15° from the equator. The general region in which they are situated has two seasons during the year, a dry or winter season which lasts from November until April, and a wet season from May to October. December and January are the coldest months of the year. During the period covered by these studies the prevailing winds blew from the southwest and at such times there was always very little or no wind at all during the earlier part of the day, but between 10 a. m. and noon a southwesterly wind would spring up and blow until about sunset, reaching a maximum strength about the middle of the afternoon. Cool northerly winds were noted twice. At lake Atitlan a strong northerly wind arose about noon on February 12 and blew continuously for a little more than three days, making the lake so rough that work had to be discontinued during this interval of time. A few days later another norther, called "norte" by the natives, was noted at lake Coatepeque.

Some idea of the daily range of the temperature of the air at two of the lakes during the visits may be obtained from the following table:

TABLE I. *Air Temperatures at Lakes Atitlan and Ilopango.*

Lake Atitlan			Lake Ilopango		
Day	Hour	Temp.	Day	Hour	Temp.
Feb. 13	5:30 p. m.	21.1° C.	Feb. 21..........	noon	27.0° C.
	9:00 p. m.	19.4		2:00 p. m.	27.5
14............	6:30 a. m.	17.2		6:00 p. m.	26.1
	1:30 p. m.	25.0	22..........	6:30 a. m.	21.4
	6:00 p. m.	20.0		2:30 p. m.	30.5
	9:00 p. m.	16.0		6:00 p. m.	21.1
15............	6:00 a. m.	17.2		9:00 p. m.	21.1
	1:30 p. m.	22.3	23..........	6:00 a. m.	17.0
	6:00 p. m.	21.0		noon	29.4
	9:00 p. m.	19.5		1:00 p. m.	29.3
16............	6:15 a. m.	16.4		3:00 p. m.	28.6
	1:30 p. m.	21.3			
	9:00 p. m.	16.2			
17............	6:00 a. m.	11.8			

At lake Amatitlan in the latter part of January, 1906, Meek[1] found by means of maximum and minimum self-registering thermometers that the lowest temperatures of the day were reached between 3 a. m. and 5 a. m. and the highest between 2 p. m. and 4 p. m. The total range varied from a minimum of 11.7° C. (53° Fahr.) to a maximum of 26.1° C. (79° Fahr.)

[1] Field Columbian Museum, Zool., Vol. VII, p. 178. 1908.

Physical Features of Lakes.

LAKE AMATITLAN.

Lake Amatitlan is situated in 90° 30′ west longitude and 14° 25′ north latitude. By rail it is 29.6 km. (18.5 mi.) from Guatemala City and 89.6 km. (56 mi.) from San José, the most important seaport of the republic of Guatemala on the Pacific coast. Its surface is about 1180 m. (3870 ft.) above sea level and some of the neighboring mountains rise to an elevation of 250 m. to 400 m. or more above the lake, thus giving the body of water the general characteristics of a typical mountain lake. A short distance southwest of the lake is the volcanic peak Pacaya, which reaches an altitude of about 2550 m. while to the south lies another volcano known as Aqua, whose altitude is given by some authorities as 3750 m. and by others as 4100 m. To the northwest of the lake the mountains consist of hard granitic rock but all of the others in this vicinity are composed largely of loose material, such as volcanic ash and pumice which are easily eroded.

The depression occupied by the lake owes its existence to the forces which produced the surrounding mountains, but the dam which impounds the waters was produced in part, perhaps, by volcanic agencies.

Along the greater portion of the lake the shore is rugged and possesses a steep slope, but about half of the north shore consists of a fairly broad, low plain which has been built by the Lobos river and the temporary streams which enter the lake from the north. (See fig. 1, p. 217.) The higher land back of this plain is composed of material which is easily eroded so that the waters coming from this region carry a large amount of débris. Even during the height of the dry season the Lobos river brings down a fairly large amount of this material which is deposited at the mouth as a typical delta formation. This plain is an excellent example of the encroachment of land on a lake. Apparently more than a third of the original area of the lake is now occupied by this plain, which is about 6 km. long by about 2 km. wide.

The lake is long and narrow, with its main axis extending almost east and west, being slightly inclined to the northwest and southeast. It is irregular in outline. The maximum length is about 13 km., and the maximum width, about 4 km. The minimum width is less than half a kilometer. The encroachment of the land on the north side has narrowed the lake very much a little east of its middle thus separating it into two basins. At the narrowest part the lake is crossed by the Ferrocarril Central de Guatemala and the resort station called Laguna is situated on the south shore in this locality.

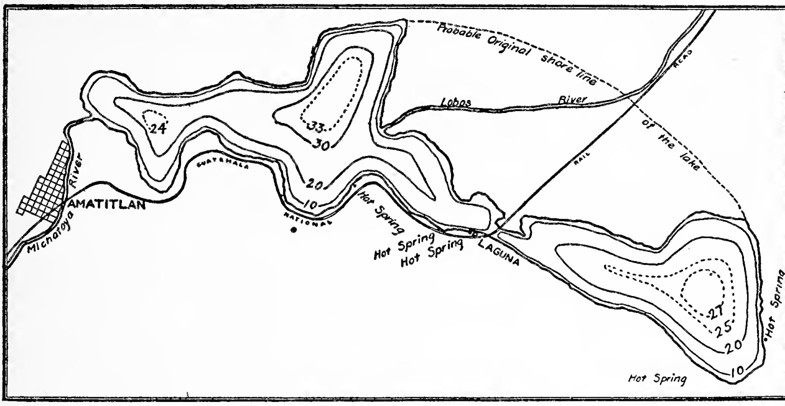

FIG. 1.—SKETCH MAP OF LAKE AMATITLAN (AFTER MEEK).

The depths are shown in meters.

The somewhat smaller, eastern portion has a maximum depth of about 29 m. and the western portion, about 34 m.

The bottom of the lake is uniform and presents a rather narrow marginal shelf; beyond this the slope is rather steep.

The chief affluent, and in fact the only permanent stream entering the lake, is the Lobos river. Along the south side and at the east end of the lake there are several warm or hot springs, the largest and hottest one being found at Laguna. The water of the latter is hot enough to boil eggs, about six minutes time being required for soft boiled eggs.[1] The waters contributed by these hot springs affect the temperature of the lake water only a few meters from the shore and then only at the surface. The surplus waters leave the lake at the western end through the Michatoya river which flows into the Pacific ocean.

The transparency of the water was rather low, a Secchi's disc 10 cm. in diameter disappearing from view at a depth of 2.75 m.

[1] Meek, loc. cit., p. 167.

With a 30 cm. disc, Meek found a transparency of about 3.5 m. The water is slightly brackish, the total solids amounting to 421 parts per million. Of this amount, sodium and potassium chloride constitute 210 parts per million. The other important constituents are as follows: Silica, 40 parts per million; iron and alumina, 6; calcium, 56; and magnesium, 7.8.

The larger aquatic plants, such as *Typha, Scirpus, Potamogeton, Ceratophyllum,* and *Chara,* are fairly abundant in the shallow water along the shores, but they grow most luxuriantly along the lowland on the north side of the lake. A floating plant, *Salvinia natans,* is widely distributed also, but it is most abundant in the vicinity of hot springs. Another floating plant, the water-lettuce or *Pistia obcordata* is found in the lake, but it is confined mainly to the low shore on the north side.

LAKE ATITLAN.

Atitlan is a mountain lake situated on the Pacific slope of Guatemala, about due west of Guatemala city. It is about 40 km. from the nearest railway station, viz., that of the village of Patulul. The lake lies at an altitude of about 1500 m. above sea level and is said to have an excellent climate during the entire year, being free from excessive heat in summer as well as unusually cool weather in winter. Coffee and tropical fruits, such as lemons, oranges, and bananas, are grown in abundance in this vicinity. With the exception of a small portion of the southern shore, the lake is bordered by mountains which rise to a general altitude of 750 m. or more above its surface. In many places the shores rise perpendicularly from the water's edge to a height of 50 m. or more.

Several craters of extinct volcanoes are found on the south side of the lake and give mute evidence of the volcanic activities that once took place in this region. The most prominent cones are Atitlan and San Pedro. The former rises about 2100 m. above the surface of the lake, and the latter about 1500 m.

The lake is fairly regular in outline with a prominent bay extending southward. (See sketch map, fig. 2, p. 219.) The maximum length is about 38 km. and the longest axis lies in a northeast-southwest direction. The maximum width is about half the length, but the mean width is not more than a third of the length. It seems probable that the basin occupied by the lake resulted from the damming of an ancient valley by the volcanoes which are situated on the south side. This is the only portion of the shore that is low and beyond it is San Lucas pass through which the lake probably discharged its surplus waters if it ever possessed an outlet.

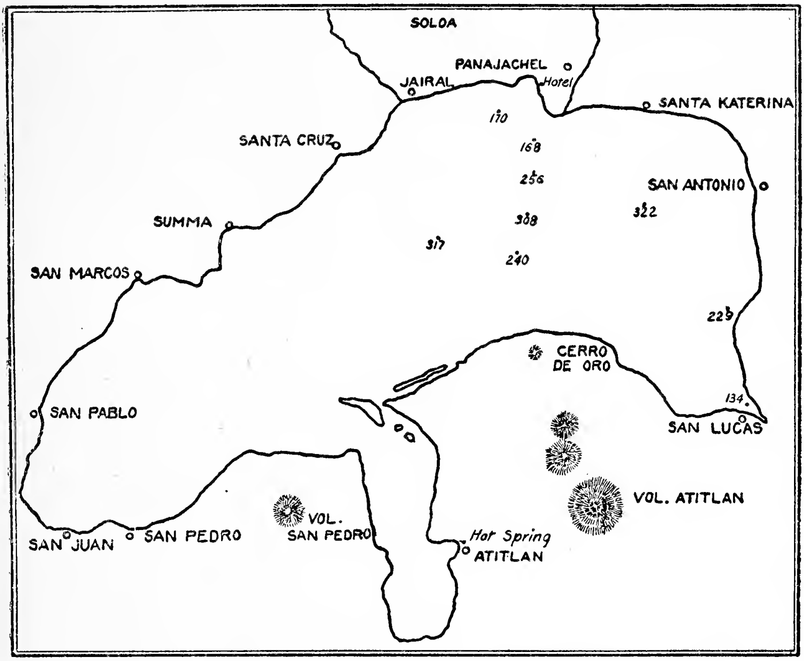

FIG. 2.—SKETCH MAP OF LAKE ATITLAN (AFTER MEEK).

The depths are shown in meters.

There are a few small affluents chiefly on the north side of the lake. The largest stream enters the lake near Jairal and the next in size enters near Panajachel. These streams drain small valleys that are about 1.5 km. wide and 3 km. to 5 km. long. A small hot spring is situated at the village of Atitlan. There is no visible outlet.

The marginal shelf along the edge of the lake is very narrow in most places and the bottom has a steep slope, a considerable depth of water being found close to the shore. This is shown also by the very small delta formations found at the mouths of the streams. While these streams are small, the height of the adjacent uplands indicates that they have removed a relatively large amount of material.

The water has a bluish-green color and is much more transparent than that of lake Amatitlan. In 1906 Meek[1] found that a white disc 30 cm. in diameter could be seen at a depth of 13.7 m. On February 15, 1910, a disc 10 cm. in diameter disappeared from view at a depth of 10 m. Meek found a maximum depth of 322 m. and a rather large portion of the lake, apparently, has a depth of 300 m. or more.

Owing to the narrowness of the marginal shelf and the steep slope of the bottom, the larger aquatic plants are rather scarce along the shore, not being able to gain a foothold in most places. They are found more frequently along the deltas of the small affluents and consist of such forms as *Typha*, *Scirpus*, *Potamogeton*, and *Chara*.

LAKE ILOPANGO.

Lake Ilopango lies in a picturesque valley about 10 km. southeast of the city of San Salvador, the capital of the republic of Salvador. It lies in 89° west longitude and 13° 42′ north latitude. The surface of the lake is about 490 m. above sea level. The longest axis of the lake lies in an east-west direction and is about 9.2 km. in extent; the maximum width is about 7.3 km.; and the area is 54.3 sq. km. (See fig. 3, p. 221.) The basin occupied by the lake appears to have had a volcanic origin, probably the coalescence of several points of eruption.[2] The region is still subject to seismic disturbances which have affected the level of the lake at various times.

Brigham states that most of the small towns in the neighborhood of Lago de Ilopango were destroyed by earthquakes on December 27 and 30, 1879. On January 11, 1880, the water of the lake had risen more than a meter and it is estimated that on the following day nearly 14,000,000 cu. m. of water were discharged through the outlet of the lake, making a stream of greater volume than the Seine at Paris. On January 20, 1880, about 11 p. m., a great disturbance was noted near the middle of the lake and the next morning a pile of rocks was seen from whose midst arose a column of vapor. These rocks now constitute two small islands near the middle of the lake. The larger island is 90 m. to 100 m. long and 20 m. to 30 m. wide and rises from 8 m. to 10 m. above

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[1] Loc. cit., p. 180.
[2] Brigham. Guatemala, the Land of the Quetzal, p. 402. N. Y., 1887.

the surface of the water. The smaller island is conical, about 20 m. in diameter and 10 m. high. The smaller lies about 200 m. north of the larger and the water between them has a depth of 45 m.

The shores are fairly steep, the east and southeast shores rising most abruptly. The surrounding country soon rises to a height of 300 m. or more above the surface of the water, the only break in the elevated rim being at the outlet. A short distance east of

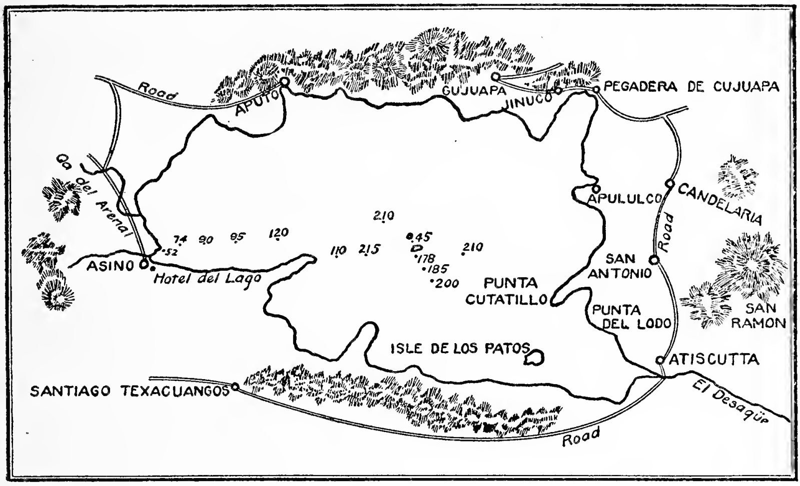

FIG. 3.—SKETCH MAP OF LAKE ILOPANGO.

The depths are shown in meters.

the lake is the lofty volcanic cone known as San Ramon. At the western end it receives a small affluent, Qa. del Arenal. This stream has built a rather large delta at the point where it enters the lake. The outlet, El Desagüe, is located at the southwestern corner of the lake, and this stream is a tributary of El Chorro, which flows into the Pacific ocean.

Several kilometers of the shore line were examined and comparatively little shallow water was found, a depth of several meters being found very near the shore. Along the northwestern shore, for example, the water descends to a depth of 52 m. within 12 m. to 15 m. of the shore cliff. This cliff has the appearance of a fault line. Soundings were not made in all parts of the lake, but those that are indicated on the accompanying map (fig. 3) show that the slope of the bottom is steep. Several years ago a maximum depth of 209 m. was found; but in the observations made in 1910, one sounding showed a depth of 215 m. The slopes of the volcanic islands below the water seem to be very steep. A sounding about 200 m. south of the larger island showed a depth of 170 m. and a depth of nearly 200 m. was found a short distance east of the islands.

Like lake Atitlan, the larger aquatic plants are not very abundant in lake Ilopango owing to the steep slopes of the bottom near shore. *Chara* seemed to be the commonest form in the shoaler water.

The water was just a little more transparent than that of Atitlan, the disc disappearing from view at a depth of 10.5 m.

The fishes inhabiting lake Ilopango are chiefly small and not very abundant.

LAKE COATEPEQUE.

The Laguna de Coatepeque is situated in the province of Santa Ana, republic of Salvador, some distance northwest of the city of San Salvador. Its geographical position is 89° 34′ 25″ west longitude and 13° 49′ 33″ north latitude. It lies about 8 km. southwest of the city of Coatepeque, which is one of the stations on the Santa Ana branch of the Salvador railroad.

The accompanying sketch map (fig. 4, p. 223) shows that the lake is almost quadrangular in outline. The east-west axis of the lake has a length of about 6.5 km. and the north-south one, about 5.5 km. The basin appears to be of volcanic origin and possesses crater-like characters. The lake is surrounded by a narrow margin of valley which has a gentle slope, but beyond this the shores rise abruptly to a height of 200 m. or more above the surface of the water, forming a continuous, unbroken rim. A short distance west of the lake are two volcanoes, Santa Ana and San Marcelino. The former rises to a height of 1830 m. above sea level. The surface of the lake is about 760 m. above sea level.

The marginal valley affords an excellent location for chalets, a number of which are situated along the southern and eastern shores. A small island is located at the southwestern corner of the lake. The lake possesses neither stream inlet nor outlet.

At the time of this visit, February 25, 1910, the water seemed to be somewhat higher than usual, as it was undercutting banks which had previously been above the horizon of the waves. The lake is said to have a maximum depth of 120 m. but only two soundings were made during this investigation. One near the middle of the lake showed a depth of 110 m. while another nearer the southern shore also gave a depth of 110 m.

The larger aquatic plants were unusually scarce along that portion of the shore which was examined.

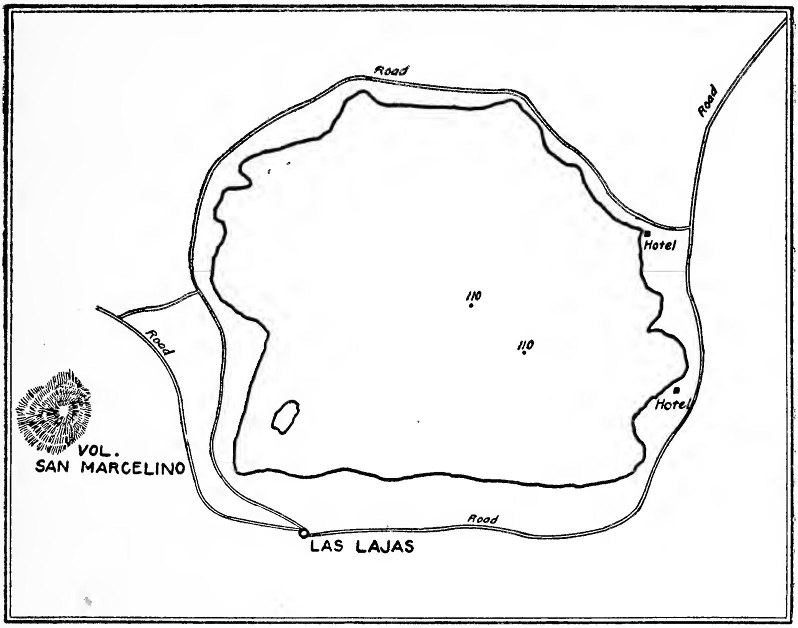

FIG. 4.—SKETCH MAP OF LAKE COATEPEQUE.

The depths are shown in meters.

The water of this lake was the most transparent of the four, a Secchi's disc 10 cm. in diameter just disappearing from view at a depth of 12.5 m.

The water contains considerable mineral matter in solution as shown by the following analysis by Renson.[1] The results are stated in parts per million:

Residue at 180°	1063.0
SiO_2	6.5
Mg	86.8
Ca	36.8

[1] Barberena, Monografias Departmentales VI, Departmento de Santa Ana. 1910, p. 13.

Na	197.7
K	34.5
SO_4	253.2
Cl	301.5

It will be noted that this water contains about two and a half times as much matter in solution as that of lake Amatitlan. Especially significant is the large amount of sodium and chlorine.

Temperatures.

All of these lakes belong to the tropical class whose waters are disturbed throughout their entire depths but once each year. That is, the so-called process of overturning and circulation is confined to the late autumn and winter months. With the advent of cooler weather in the autumn, the temperature of the upper water begins to fall. The cooling takes place at the surface and it results in the formation of convection currents which aid in the mixture of the upper strata of water. These currents affect the water to greater and greater depths as the cooling progresses. The wind, however, is a more active as well as a more important agent in causing the mixture and circulation of the upper water. As the cooling progresses and the temperature of the upper water approaches that of the lower, the thickness of the stratum that is disturbed by the wind gradually increases. Finally the thermal resistance to the mixture of these two strata becomes so small that the wind is able to produce a general mixture of the water from surface to bottom. This is known as the autumnal overturning and it probably takes place between the middle of November and the middle of December. Owing to differences in altitude as well as in latitude the time is different for the different lakes. There are, doubtless, variations in the same lake from year to year owing to annual differences in the weather.

This overturning is followed by a period during which the water is subject to disturbance by the wind throughout its entire depth. This is the socalled period of circulation. During its existence the water has a uniform temperature from surface to bottom; that is, the lake is homothermous. The exact time at which this circulation ceases is not known, but in 1910 it took place in all four lakes previous to the time of these observations.

The minimum temperatures which were reached by the waters of these lakes in the winter of 1909–10 are shown by the bottom temperatures obtained in these observations. The minimum temperature depends upon the severity of the winter and doubtless it varies somewhat from year to year. In late January and early February, 1906, Meek found that the temperature of the bottom water of lake Amatitlan was 20.5° C. while on February 5, 1910, it was 19.6°. In lake Atitlan the bottom temperature was 20.0° in February, 1906, and 19.2° in February, 1910.

In this latitude day and night are about equal in length so that the diurnal period of radiation is substantially equal to that of insolation. Such a condition is not favorable for the storing of a large amount of heat in the upper stratum, but during the latter part of January this water begins to gain heat and this process continues until the temperature of the upper water rises a few degrees above that of the lower. As the temperature of the surface water rises it becomes lighter than the water below and offers a resistance to mixture with it. Soon this thermal resistance reaches a point where the wind is no longer able to mix the upper water with the somewhat cooler water below and the water of these tropical lakes becomes directly stratified just as it does in temperate lakes in early summer. Such a stratification was found in these southern lakes in February, 1910. The temperature differences were not great enough to show the exact limits of the three different strata, that is, the layers which correspond to the epilimnion, the thermocline or mesolimnion, and the hypolimnion in temperate lakes after their stratification; but taken in connection with the results obtained for dissolved gases, they show that similar strata existed at the time of these observations. Owing to differences in area, depth, and climatic conditions, the thickness of these layers differed in the different lakes.

In lake Amatitlan, the middle stratum or mesolimnion lay between 10 m. and 20 m. and the temperature at the latter depth was only 0.5° less than at the former. In lake Ilopango this zone had the same extremes or limits with a difference in temperature of 0.6°. In lake Coatepeque, however, the middle stratum lay between 20 m. and 30 m. and there was a decrease of 0.5° in this layer. In lake Atitlan the difference in temperature between surface and bottom was only about 0.4° in the early part of the day and the greater part of this difference was found in the upper 10 m. The middle or insulating stratum had not yet become definitely defined thermally, but the results obtained from dissolved gases showed that the lower strata no longer took part in the general circulation of the water. The decrease in the alkalinity between 75m. and 100 m. indicates that this stratum was at the lower limit of the circulation. As the season advanced and the upper water became warmer, this transition zone undoubtedly came much nearer the surface, very probably lying at a depth not exceeding 20 m. to 30 m.

The effectiveness of the slight differences in temperature in preventing the mixture of the water at all depths doubtless finds its explanation in the fact that the waters had such a high temperature. The thermal resistance to mixture due to a rise in temperature of water from 19° to 20° is 25 times as great as that due to a rise from 4° to 5°.[1] That is, it would require twenty-five times as much work to mix two given volumes of water at temperatures of 19° and 20° as it would take to mix the same volumes of water if their temperatures were 4° and 5° respectively. Thus, since the lowest temperature in these tropical lakes was about 19°, a slight rise in the temperature of the upper water would produce a marked increase in its thermal resistance to mixture with the somewhat cooler water below. The maximum rise in the temperature of the upper water during the summer most probably does not exceed a few degrees because day and night are about equal in length in this latitude, thus giving as much time for the radiation as for the accumulation of heat. But this relatively small increase in the temperature of the upper water undoubtedly causes the three strata to become sharply defined. In fact, it seems probable that they become so well marked that the resistance to mixture offered by the transition zone, or middle stratum, is comparable to that offered by the thermocline or mesolimnion of the deeper lakes of the temperate zone in summer.

The waters of lake Ilopango were warmest and those of lake Atitlan were coolest. (See table II, p. 244.) The differences in temperature were due chiefly to differences in the altitude of the various lakes, the former lying at the lowest altitude, while the latter lies at the highest. The maximum difference between surface and bottom temperature was found in lake Coatepeque.

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[1] Birge, Trans. Wis. Acad. Sci., Arts, & Letts., Vol. XVI, Part 2, 1910, p. 992.

The results obtained on these lakes are not in agreement with those obtained by Downes[1] on water reservoirs situated in the Panama Canal Zone. He found that these artificial bodies of water were permanently stratified and that the transition zone lay at a depth of only 2 m. to 3 m.

Dissolved Gases.

Oxygen. Samples for the estimation of the dissolved gases were obtained by means of a closing water bottle which had a capacity of about one liter. The sample bottles had a capacity of about 250 cc. so that three samples of water were obtained from each depth at a single haul. Two of these samples were used for the determination of the dissolved oxygen and the third for carbon dioxide. The water was transferred from the water bottle to the sample bottles by means of a rubber tube and precautions were taken to prevent contact with the air. The surplus water was used to flush out the bottles containing the oxygen samples. The Winkler method was used for the determination of the quantity of dissolved oxygen and in general the results given in the table are the mean of duplicate samples.

In this method of determining the dissolved oxygen, 1 cc. of a solution of maganous chloride is added to the sample and then 1 cc. of a solution containing sodium hydroxide and potassium iodide. The sample is thoroughly shaken and the precipitate is allowed to settle. It is now treated with 2 cc. of concentrated, chemically pure hydrochloric acid, which dissolves the percipitate. In the chemical reactions which take place, iodine is liberated in proportion to the amount of dissolved oxygen present. The amount of the free iodine is then determined by titration with a standard solution of sodium thiosulphate. One cubic centimeter of a N/10 sodium thiosulphate solution is equivalent to 0.0008 gm., or 0.5598 cc. of oxygen at 0° and 760 mm. since 1 l. of oxygen weighs 1.429 gms. at normal temperature and pressure.

During the winter circulation the general mixing of the water at all depths is sufficient to produce a fairly uniform distribution of the dissolved gases and other substances held in solution. The water at various depths is exposed to the air from time to

[1] A Study of the Water Supplies of the Isthmus of Panama. Proc. Med. Asso. of Isthmus of Panama, vol. III, 1911, p. 133–150, 7 pls.

time where it may obtain more oxygen in case its supply of this gas is deficient. Through the influence of the wind this aerated water is forced down into the lower strata and mixed with the deeper water, thus carrying down a supply of dissolved oxygen. This process continues during the period of complete circulation and results in a pretty thorough aeration of the water at all depths. The upper water also receives some oxygen through the process of photosynthesis, since in this process the chlorophyll-bearing organisms, under the influence of light, take up carbon dioxide and liberate oxygen. The decrease in the temperature of the water in autumn and winter increases its capacity for oxygen, since this gas is more soluble in cold than in warm water. As a result of the circulation and the increase in the capacity of the water for this gas, the largest quantity of oxygen held in solution by the waters of these lakes is found just at the close of the circulation period.

As soon as the lower water ceases to take part in the circulation it is cut off from further addition to its supply of dissolved oxygen because this gas diffuses so slowly through water that the amount transferred in this way is negligible. Hence the supply is limited to the amount which this water contains at the time that it ceases to take part in the circulation. Soon an appreciable decrease in the dissolved oxygen of the lower water is noted. This decrease is the resultant of two processes, namely, respiration and decomposition. The lower strata are inhabited by various organisms which consume dissolved oxygen in their process of respiration and liberate carbon dioxide. But probably a much larger portion is consumed in the decomposition of organic material. Especially is this true when the upper water supports a large population of plankton organisms, more particularly phytoplankton. The decrease is most rapid at the bottom because decomposable material is most abundant there.

But decomposition takes place at all depths. The floating devices possessed by the various phytoplankton forms reduce their specific gravity so that it is but little greater than that of the water. Thus such organisms sink very slowly when they are dead and they may pass through the early stages of decay, at least, at almost any depth. When this decomposition takes place in the upper water the dissolved oxygen which is consumed in this process may be replenished because this stratum is kept in circulation by the wind. Also, the photosynthesis which takes place in this layer aids in maintaining a supply of oxygen. But the water which lies below the zone of circulation is not able to replenish its losses of oxygen until the next period of overturning and circulation.

Table II, (p. 244) shows that the bottom waters of lakes Amatitlan and Ilopango contained a distinctly smaller amount of dissolved oxygen than their surface waters. The difference between surface and bottom in the former lake was 2.5 cc. per liter of water and in the latter almost 2 cc. In both lakes the most marked decrease came in the 10-15 meter stratum. There was an appreciable difference between surface and bottom in lakes Atitlan and Coatepeque, but it was not nearly so marked as in the other two lakes. In the former it amounted to only about 0.5 cc. and in the latter about 0.6 cc.

As the season progresses the difference between surface and bottom undoubtedly becomes more marked in all of the lakes. In fact, it seems very probable that the dissolved oxygen is entirely exhausted in some of the lower water of both Amatitlan and Ilopango lakes before the autumnal overturning takes place. In lake Atitlan the volume of the lower water is relatively very great so that it holds a correspondingly large amount of oxygen in solution; the amount is so large, in fact, that the demands for oxygen in the lower strata may not be great enough to entirely exhaust the supply in any of this water.

Downes[1] found that the water in some of the reservoirs of the Panama Canal Zone was permanently stratified and that, below a depth of 3 m., there was practically no dissolved oxygen throughout the year.

The percentages of oxygen saturation shown in the last column of table II (p. 244) are based upon the quantity of oxygen required for the saturation of perfectly fresh or distilled water as shown by Fox's[2] determinations. It will be noted that these percentages are low, even at the surface where the water is freely exposed to the air. The highest percentage of saturation was found in lake Amatitlan and the lowest in lake Atitlan. The quantity of oxygen absorbed by the waters of these lakes is affected by two factors, namely, the salinity of the waters and the elevation of the lakes above sea level. The presence of sodium chloride reduces the capacity for oxygen. Chemical

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[1] Proc. Med. Asso. of Isthmus of Panama, vol. III, p. 133–150, 7 pls. 1911.
[2] Publications de circonstance, No. 41, Part I, 25 p., 1 pl. 1907.

analyses of the water of lakes Amatitlan and Coatepeque show that rather large amounts of this substance are found in them and this would reduce materially their capacity for the absorption of oxygen. With increase in altitude there is a decrease in atmospheric pressure; this means a corresponding decrease in the tension of the oxygen and the amount absorbed by water will be correspondingly smaller. The decrease in the amount of oxygen absorbed is about one per cent. for every 82 m. (270 ft.) above sea level.

On this basis the saturation point at the altitude of lake Amatitlan is 14.3 per cent. below that at sea level, or 85.7 per cent. Since the quantity of oxygen in the upper water amounted to about 90 per cent. of saturation at sea level, it was actually somewhat above the saturation point for the altitude of the lake. The excess was due to the activities of the chlophyll-bearing organisms which were abundant in the upper strata.

At the altitude of lake Atitlan the saturation point is only about 82 per cent. of that at sea level. But the quantity of dissolved oxygen in the upper strata amounted to only 66 to 69 per cent. which still left a deficiency of 13 to 16 per cent. The altitude of lake Ilopango accounts for only 6 per cent. of the 16 per cent. deficiency, thus leaving 10 per cent. to be attributed to other factors. In the upper 20 m. of lake Coatepeque the quantity of dissolved oxygen was from 15 to 19 per cent. below the saturation point at sea level. About 9 per cent. of this deficiency can be attributed to the altitude of the lake which leaves 6 to 10 per cent. still unaccounted for.

In the latter part of table II (p. 244) are shown the results for dissolved gases which were obtained on two of the Finger Lakes in the state of New York. These two bodies of water, namely Cayuga and Seneca lakes, belong to the deeper class of temperate lakes and they compare very favorably in depth with three of these tropical lakes, lake Amatitlan being the exception. It will be noted that there was a marked difference between the temperate and tropical lakes with respect to the amount of dissolved oxygen found in their waters. The quantity was distinctly larger in the former than in the latter at all depths. The large amount of this gas found in the lower waters of the temperate lakes was due to the low temperatures in these strata which gave the water a much greater capacity for oxygen. At the time of the observations the surface layers of Amatitlan and Cayuga lakes had the same temperature, yet the former contained one cubic centimeter of oxygen per liter of water less than the latter. But if the altitude of the two lakes is taken into account, the amount of oxygen in the surface stratum of lake Amatitlan was about 4 per cent. above the saturation point while in Cayuga lake it was somewhat less than 2 per cent. in excess.

The surface temperatures of Atitlan and Seneca lakes were the same but the dissolved oxygen of the former amounted to 2.1 cc. less than that of the latter. If corrections be made for the altitudes of the two lakes, the quantity of oxygen in the surface water of Seneca lake was about 6 per cent. above saturation while that in the surface water of lake Atitlan was about 13 per cent. below the saturation point. With respect to the volume of oxygen found at the various depths it may be said that the observations were made on the temperate lakes in August when the quantity of this gas was near the minimum for the year, while on the tropical lakes they were made soon after the close of the winter period of circulation, and at that time their waters should contain about the maximum amount for the year.

Carbon dioxide. The Seyler method[1] was used for the determination of the carbon dioxide. In this method the degree of alkalinity or acidity of the water is obtained by titration with a standard solution of an acid or an alkali, as may be necessary, using phenolphthalein as an indicator. The fixed carbon dioxide is determined by titrating with a standard solution of an acid, using methyl orange as an indicator. For these determinations N/44 Na_2CO_3 and N/44 HCl were used.

The greater portion of the carbon dioxide of lake waters is generally found in chemical union with other substances, chief among which are calcium and magnesium. This combined gas exists in two different states. One portion is in a close chemical union with these substances and forms their normal carbonates. This is known as the fixed or combined carbon dioxide. The other part is in a loose union and comprises that portion of this gas which converts the normal carbonates into the bicarbonates. It is called the half-bound or bicarbonate carbon dioxide. The latter is in such a loose chemical union that the chlorophyllous organisms are able to use the greater part of it in their photo-

[1] Chem. News, vol. 70, 1894, p. 82, 104, 112, 140 and 151.

synthetic activities. This makes the half bound carbon dioxide a very important factor from the biological standpoint.

Whenever this gas is present in excess of the amount required for the conversion of the normal carbonates into bicarbonates, it appears in the form of free carbon dioxide and such a water will give an acid reaction with phenolphthalein. On the other hand, when no free carbon dioxide is present and some of the half bound carbon dioxide is lost, leaving an excess of the normal carbonate, the water gives an alkaline reaction with this indicator. In table II (p. 244) the degree of alkalinity or acidity of the water is shown in terms of carbon dioxide. The minus sign shows that the water gave an alkaline reaction with phenolphthalein and the numbers indicate the amount of free carbon dioxide necessary to produce a neutral reaction. The plus sign indicates that the water gave an acid reaction and the degree of acidity is stated in terms of free carbon dioxide.

In lake Amatitlan the water was distinctly alkaline down to a depth of 15 m. so that it would have required 3.34 cc. of free carbon dioxide per liter to make it neutral. It was neutral at 20 m. and 25 m. and acid thence to the bottom where the acidity was equivalent to 2.78 cc. of free carbon dioxide per liter of water. Similar results for free carbon dioxide are found in temperate lakes soon after the summer stratification has been well established.

In lake Atitlan the water gave an alkaline reaction at all depths. In the upper 70 m. the alkalinity was equivalent to 2.23 cc. of free carbon dioxide per liter of water and it amounted to only 1.11 cc. at and below 200 m. The water of a thermal spring located at the village of Atitlan had an acidity equivalent to 23.26 cc. of free carbon dioxide per liter, while the fixed carbon dioxide amounted to 124.65 cc.

The water of lake Coatepeque had the highest degree of alkalinity. In the upper 20 m. it amounted to 5.57 cc. while below 75 m. it was equivalent to 3.23 cc. (See table II, p. 244.)

During the period of complete circulation the water in each of these three lakes doubtless had a substantially uniform degree of alkalinity, but when the lower water ceased to take part in the circulation its alkalinity began to decrease. This result was due to the liberation of carbon dioxide in the respiration of the organisms which occupied this stratum and in the decomposition of organic material which also took place in this region.

Unlike the other three lakes the water of lake Ilopango gave an acid reaction at all depths. In the upper 25 m. the acidity was equivalent to 2.78 cc. of free carbon dioxide per liter of water, while in the bottom stratum it amounted to 7.23 cc. Such a marked acidity following so soon after the winter period of circulation would seem to indicate that the water of this lake at all depths may have an acid reaction throughout the year. Similar results have been obtained on soft water lakes in Wisconsin, except that such a high degree of acidity has not been found in the upper water of the latter lakes, their acidity rarely exceeding one cubic centimeter per liter of water in the epilimnion. Also in temperate lakes which possess as large an amount of fixed carbon dioxide as lake Ilopango the water becomes alkaline soon after the vernal overturning has taken place and the water of the epilimnion, at least, remains more or less alkaline until the time of the autumnal overturn. But the bottom water of such a lake may possess a very high degree of acidity toward the close of the summer period of stratification. At this time it may be equivalent to as much as 30 cc. to 50 cc. of free carbon dioxide per liter of water. Doubtless the acidity of the lower water in lake Ilopango becomes much greater as the season advances, and it may equal or exceed that of these temperate lakes just before the winter period of circulation is inaugurated.

In general there are four sources of carbon dioxide for lake waters. They are (1) the air, (2) the decomposition of organic substances, (3) the respiration of the organisms inhabiting the water, and (4) ground waters. The atmosphere contains from three to four parts of carbon dioxide per 10,000 so that water which is freely exposed to the air absorbs a small amount of this gas. But only a relatively small amount is obtained from this source because it is absorbed only in proportion to its partial pressure which is slight. Lake waters are generally well populated with organisms which furnish a supply of decomposable material at their death. The decomposition takes place at all depths but is most vigorous at the bottom where the organic material is most abundant. In their respiration these organisms consume dissolved oxygen and liberate carbon dioxide. Many of the lower organisms are able to live in water which contains no free oxygen, but in the intra-molecular respiration which they carry on a certain amount of carbon dioxide is doubtless imparted to the water.

Rainwater possesses a small amount of carbon dioxide when it reaches the earth and in passing through the ground it obtains still more. The normal carbonates of calcium and magnesium are only slightly soluble in pure water, but this carbonated water readily changes the comparatively insoluble normal carbonates to the much more soluble acid carbonates or bicarbonates. Thus, when this ground water reaches a lake through springs, it generally contains a liberal amount of both bicarbonates and free carbon dioxide. But, unless the volume of spring water entering a lake is relatively large in proportion to the volume of the lake, the free carbon dioxide content of the whole body of water is not greatly affected from this source.

The unusual acidity of the water in lake Ilopango was not due to the absorption of carbon dioxide from the air because the quantity was larger than would naturally be obtained from this source owing to the low partial pressure of this gas in the atmosphere. Neither was there any evidence that it was due to carbon dioxide derived from decomposition and respiration. These processes would have to be taking place very vigorously in order to maintain such a high degree of acidity in the upper water which was kept in circulation by the wind and freely exposed to the air where the tendency would be to dispose of any excess of this gas. But there was no indication that these processes were proceeding with such vigor. The fact that there were about 3 cc. of dissolved oxygen per liter of water at the bottom shows also that the 7.23 cc. of carbon dioxide in this water did not come entirely from respiration and decomposition because, if it had been produced by these processes, the free oxygen would all have been consumed in its production.

Of the sources mentioned above, there remains, then, only the ground water to be considered. Ordinary spring waters generally contain an abundance of free carbon dioxide and when the volume of water derived from springs is relatively large in proportion to the volume of the lake, the acidity of the lake water is affected appreciably. But in a lake having as large a volume of water as lake Ilopango, it would require an unusually large inflow of spring water to produce and maintain such a high degree of acidity as was shown by the waters of this lake. No definite data were obtained relative to the volume of spring water entering lake Ilopango, but about a quarter of the shore was examined and no springs were noted along this portion. Also the volume of the water discharged through the outlet stream does not seem to indicate that the lake receives an unusually large amount of spring water. As noted above, the water of the thermal spring at lake Atitlan possessed a high degree of acidity and, since lake Ilopango is situated in a region that is affected by volcanic disturbances, it seems more probable that the acidity of its water is mainly of volcanic origin rather than derived from the usual sources noted above.

Lake Amatitlan had the smallest amount of fixed carbon dioxide with 32.28 cc. per liter of water and Atitlan came next in order with 37.84 cc. (See table II, p. 244.) The other two lakes had distinctly larger amounts, Ilopango having an average of about 48 cc. and Coatepeque about 56 cc. It will be noted that all of these tropical lakes possessed a distinctly larger amount of fixed carbon dioxide than Cayuga and Seneca lakes in the state of New York. In fact Ilopango and Coatepeque contained more than twice as much as these temperate lakes.

With respect to the amount of this gas these four Central American lakes belong to the same class as the majority of the lakes in southeastern Wisconsin. In this quarter of the state the waters of most of the lakes that have been tested so far, possess between 30 cc. and 45 cc. of fixed carbon dioxide per liter. Only one of these lakes, however, reaches an average of 48 cc. to 50 cc. Toward the end of the summer period of stagnation the bottom water in some of these temperate lakes contains a larger amount of fixed carbon dioxide, but this is found only in lakes where the bottom water becomes highly charged with free carbon dioxide. This highly carbonated water acts upon the comparatively insoluble normal carbonates in the bottom mud and converts them into the readily soluble bicarbonates. The maximum amount of fixed carbon dioxide that has been found in the bottom water of any of the Wisconsin lakes was found in Garvin lake on two different dates in 1909. It amounted to 63.2 cc. but the surface water on these dates contained respectively 35.9 cc. and 34.7 cc.

The Net Plankton.

Plankton catches were made in each of these four tropical lakes at the same time that samples of water were obtained for the chemical tests. They were taken with a vertical closing net whose straining surface was made of No. 20 silk bolting cloth. No attempt was made to study those plankton organisms which are so small that they readily pass through the meshes of the bolting cloth, to which the term nannoplankton has recently been applied. The hauls were quantitative in nature and they give a fair idea of the vertical distribution of the various forms constituting the net plankton. The number of organisms in each catch was determined by the counting method. This number was multiplied by the factor representing the coefficient of the net. This factor was determined by means of a tube 3 m. long and 10 cm. in diameter. At the lower end this tube was fitted with a sliding door which carried a bolting cloth strainer and a removable plankton bucket. The tube was lowered into the water while open, then the door was drawn over the lower end by means of a line and the tube raised, so that the water within it was strained and the plankton concentrated in the bucket. Then the net was hauled through the same stratum and the number of plankton organisms obtained in the two catches was ascertained by counting.

The results given in table III (p. 246) show the number of individuals per cubic meter of water in the various strata.

Lake Amatitlan.—The phytoplankton of this lake was characterized by the great preponderance of diatoms, of which *Melosira* was by far the most abundant form. It reached a maximum of nearly eleven million filaments per cubic meter of water in the 0-5 m. stratum. *Synedra* came next in point of abundance. *Clathrocystis* was the most abundant blue-green alga, but the maximum number of this form was found in the bottom stratum. This was probably an indication of senility; the form having passed its period of maximum development, the senile individuals had sunk into the lower water. The material from lake Amatitlan contained a greater variety of phytoplankton forms than that from any of the other three lakes.

Ceratium was the most abundant protozoan. The maximum number, more than a million per cubic meter, was found in the 0-5 m. stratum.

The rotifers were represented by *Triarthra longiseta, Anuraea stipitata,* and *Pedalion fennicum. Triarthra* was found only in the 15-20 m. stratum, and *Anuraea* was rather evenly distributed through all strata of the lake. *Pedalion* was not found in the upper 10 m. but was present at all depths below this stratum. It was most abundant in the 20-25 m. stratum.

Copepods and their nauplii were found at all depths, but they were most abundant in the 0-5 m. stratum. *Diaptomus* was more abundant than *Cyclops* in the upper 10 m., but below this depth the latter was more abundant.

The cladocera were represented by *Daphnia longispina* var. *hyalina*, *Ceriodaphnia pulchella*, *Ceriodaphnia lacustris*, and *Bosmina longirostris*. The first three forms were present at all depths, but *Bosmina* was confined to the upper 20 m. *Daphnia* was more aboundant than the other three cladocera and they all reached their maximum numbers in the 0-5 m. stratum.

Lake Atitlan.—The phytoplankton was very abundant in this lake but consisted almost entirely of *Melosira granulata*. This form was most numerous in the upper 15 m. where the average number was more than 46 million per cubic meter. A few specimens of *Gloeocapsa* and *Zygnema* were found in the upper 15 m.

Four rotifers were found in the catches, *Polyarthra platyptera*, *Anuraea stipitata*, *Brachionus pala*, and a Bdelloid form. *Polyarthra* was noted in only one catch, that made in the 5-15 m. layer. *Anuraea* was found only between 5 m. and 30 m. *Brachionus* was by far the most abundant rotifer and was present in the catches from all depths. The maximum number was in the catch from the 15-30 m. stratum. This form was also found in considerable numbers in the littoral as well as in the limnetic region. A very few specimens of a Bdelloid rotifer were noted.

Cyclops was the only copepod noted in the catches from lake Atitlan. It did not occupy the 0-5 m. stratum but was present at all other depths. It was most abundant between 5 m. and 30 m. The nauplii were distributed from surface to bottom but they, too, reached their maximum number between 5 m. and 30 m.

Five cladocerans were found in the catches, namely *Daphnia longispina* var. *hyalina*, *Daphnia pulex*, *Diaphanosoma brachyurum*, *Ceriodaphnia pulchella*, and *Bosmina obtusirostris*. All were absent from the 0–5 m. stratum and *D. pulex* was not noted in the upper 100 m. Both *Diaphanosoma* and *Ceriodaphnia* were confined to the upper strata as in temperate lakes in summer; they were found only between 5 m. and 15 m. Both *Daphnia hyalina* and *Bosmina* were present in all catches below 5 m., but they were most numerous between 5 m. and 15 m.

In one of the bottom hauls two specimens of *Hyalella dentata* were obtained.

Lake Ilopango.—The net plankton of lake Ilopango was characterized by the scarcity of the phytoplankton. Relatively small numbers of *Cyclotella* and *Synedra* were obtained in the upper 25 m. *Zygnema* was the only other alga noted in the catches. A few specimens of it were found in the upper 10 m.

The protozoa were represented by a few specimens of *Dinobryon* in the upper 10 m. and by a considerable number of *Tintinnus.* The latter was found throughout the depth of the lake, but was most numerous in the 10-25 m. stratum.

Pedalion fennicum was the only rotifer obtained throughout the depth of the lake. It was very abundant in the upper 10 m. *Anuraea stipitata* and *Notholca longispina* were found only in the 25-50 m. catch.

The only copepod noted was *Diaptomus siciloides* which was present at all depths, but was most abundant between 10 m. and 25 m. Nauplii were present in small numbers at all depths.

Only one cladoceran was noted. A few specimens of *Ceriodaphnia pulchella* were found between 10 m. and 50 m.

Coatepeque lake.—The net plankton of this lake was also poor in phytoplankton, but it was not as poor as that of lake Ilopango. Here, too, a diatom, *Cyclotella,* was the most abundant form. It was scarce in the upper 25 m., but was distinctly more plentiful below this depth, the maximum number being found in the bottom stratum. This distribution seems to indicate that this form was on the decline.

The blue-green algae were represented by a small number of *Clathrocystis* in the upper 25 m. and by a still smaller number of *Aphanizomenon* in the upper 10 m.

Ceratium and *Tintinnus* were the protozoan representatives. The former was present in relatively small numbers throughout the depth of the lake. The latter was much more abundant, with the maximum number in the upper 25 m.

The rotifers were represented by a contracted Bdelloid form, probably belonging to the genus *Rotifer,* and by *Pedalion fennicum.* The former was abundant in the upper 25 m. and a very few of the latter were found in this stratum.

The copepods were represented only by *Diaptomus sicilis* which was found at all depths, but which was most abundant in the upper 10 m. A small number of nauplii was noted from surface to bottom.

The cladocera consisted of *Daphnia longispina* var. *hyalina* and *Ceriodaphnia pulchella.* A very few specimens of the former were found below 50 m. The latter was fairly abundant in the upper 25 m.

The general results that have been obtained by marine planktologists show that plankton organisms are present in much smaller numbers in the tropical parts of the sea than in the temperate latitudes, or even within the polar circles. To cite but a single instance, Lohmann[1] found a much larger number of organisms north of 30° north latitude and south of 25° south latitude in the Atlantic ocean than between these two parallels. In the main the greater number in the higher latitudes was due to a greater variety of forms, the most conspicuous increase being due to diatoms. But the Coccolithophoridae and the Peridinidae, which were the common forms from the English Channel to Buenos Ayres, also reached their maximum numbers beyond the parallels mentioned above.

Table III (p. 246) shows that there was no marked paucity of net plankton in these four tropical lakes at the time of these observations. In fact the material compares very favorably in quantity with that of lakes situated in temperate latitudes. The shallowest member of these tropical lakes, Amatitlan, possessed the greatest variety of forms. With the exception of its rotifer population the abundance and variety of forms were quite as great as might be expected from temperate lakes of similar size and depth.

A few months after the observations were made on these tropical lakes i. e., in August, 1910, similar observations were made on several of the Finger Lakes in the state of New York. In both instances, the catches were made with the same net and the material was preserved and counted in the same manner. The results obtained with the vertical closing net on the shallower of the Finger Lakes have already been published, but those obtained in the same manner in Cayuga and Seneca lakes, the deeper of the Finger Lakes, have not been published hitherto and are included here in the latter part of table III (p. 246) for the purpose of comparing these catches with those obtained on the deeper tropical lakes.

A comparison of the cladoceran population of lakes Atitlan

[1] Veroeffentlich. d. Instituts f. Meeresk., Univ. Berlin, N. F., Geogr. Naturwiss. Reihe, Heft 1, 1912. 92 p., 2 pl.

and Cayuga shows that the number was somewhat greater in the upper water of the latter, but the former possessed a greater variety of forms. The copepods were represented only by the genus *Cyclops* in lake Atitlan, but by both *Cyclops* and *Diaptomus* in Cayuga. The number of copepods was very much greater in Atitlan than in Cayuga.

There was a very marked difference in the rotifer population of these two lakes, Cayuga having a much larger number as well as a greater variety. The protozoa were not represented in the catches from Atitlan but these forms constituted a very important element of the plankton of Cayuga.

The total number of algae was much greater in Atitlan but this superiority in numbers was due to the presence of only one species, namely, *Melosira granulata.*

When lakes Atitlan and Seneca are compared the results are still more favorable to the former. It possessed a larger number and variety of cladocera and a distinctly larger number of copepods. The rotifer population of the two lakes did not differ so greatly in number but there was a distinctly greater variety in Seneca lake. The protozoan population was comparatively small in Seneca and absent in Atitlan. The total number of algae was very much smaller in Seneca lake but it possessed a greater variety of forms.

Lake Ilopango possessed a very much smaller number of cladocera than either Cayuga or Seneca lakes and the copepoda were represented only by *Diaptomus siciloides* and its nauplii. In lake Ilopango the rotifers belonged to but three genera while in Cayuga and Seneca at least nine genera were present. In point of number of individuals Ilopango far outranked the temperate lakes owing to the presence of such large numbers of *Pedalion fennicum,* a brackish water rotifer.

The protozoan population of Ilopango greatly exceeded in number that of Seneca lake, but was smaller than that of Cayuga. In Ilopango the algae were represented only by a few diatoms, while the net catches from Seneca lake contained a few blue-greens and a fair number of diatoms; those of Cayuga lake also contained a relatively small number of blue-green algae, but a fairly large number of diatoms.

The cladoceran population of lake Coatepeque consisted of two forms, *Daphnia hyalina* and *Ceriodaphnia pulchella.* The copepods were represented only by *Diaptomus sicilis* whose numbers greatly exceeded the total copepod population of either of the two temperate lakes.

Here, as in the other tropical lakes, the rotifer population was limited to very few forms, but two in this instance. Protozoa were nearly as numerous as in Cayuga lake and greatly exceeded the number in Seneca.

Excluding the diatoms, the number of algae was not very different in the three lakes. The diatoms were more abundant in Coatepeque than in Seneca lake, but the number in the former was much smaller than in Cayuga lake.

List of Plankton Crustacea.

In addition to the collections made at the four lakes which were visited, material was also obtained at the following places: Puerto Barrios, Los Amates, and from the mangrove swamp at San José, Guatemala; from the Sunken Gardens and Lakeside Tivoli at Mexico City, and in the vicinity of San Cristobal near Mexico City. In the following list the various forms which were found in the material are indicated, together with the localities in which they were obtained.

CALANIDAE.

Osphranticum labronectum Forbes. Puerto Barrios, Los Amates.

Diaptomus siciloides Lilljeborg. Lake Ilopango.

Diaptomus albuquerquensis Herrick. Lake Amatitlan, Mexico City.

Diaptomus marshi Juday. Puerto Barrios, Los Amates.

Diaptomus sicilis Forbes. Lake Coatepeque.

CYCLOPIDAE.

Cyclops ater Herrick. Mexico City.

Cyclops viridis Jurine. Mexico City, San Cristobal.

Cyclops albidus Jurine. Puerto Barrios, Los Amates, Mexico City.

Cyclops fuscus Jurine. Lake Atitlan, Mexico City.

Cyclops serrulatus Fischer. Lakes Amatitlan and Atitlan, Los Amates, Mexico City, San Cristobal.

Cyclops prasinus Fischer. Lakes Amatitlan and Atitlan, San Cristobal.

Cyclops phaleratus Koch. Los Amates.

Cyclops bicolor Sars. Mangrove swamp at San José, Mexico City.

Cyclops fimbriatus Fischer. Puerto Barrios.

CLADOCERA.

Diaphanosoma brachyurum Liévan. Puerto Barrios, lake Atitlan, Mexico City.

Pseudosida bidentata Herrick. Puerto Barrios.

Pseudosida tridentata Herrick. Los Amates.

Parasida ramosa Daday. Puerto Barrios.

Daphnia longispina var. *hyalina* Leydig. Lakes Amatitlan, Atitlan, and Coatepeque.

Daphnia pulex De Geer. Lake Atitlan.

Simocephalus vetulus O. F. Mueller. Mexico City.

Simocephalus serrulatus Koch. Los Amates.

Ceriodaphnia pulchella Sars. Lakes Amatitlan, Atitlan, Ilopango, and Coatepeque, and Mexico City.

Ceriodaphnia lacustris Birge. Lake Amatitlan.

Bosmina longirostris O. F. Mueller. Lakes Amatitlan and Ilopango, Mexico City.

Bosmina obtusirostris Sars. Lake Atitlan.

Ilyocryptus spinifer Herrick. Lake Atitlan, Mexico City.

Macrothrix laticornis Jurine. Lake Atitlan.

Macrothrix rosea Jurine. Puerto Barrios, Los Amates, Mexico City.

Eurycercus lamellatus O. F. Mueller. Mexico City.

Camptocercus rectirostris Schoedler. Lake Atitlan.

Kurzia latissima Kurz. Mexico City.

Alona costata Sars. Lake Atitlan, Mexico City.

Graptoleberis testudinaria Fischer. Lake Atitlan, Mexico City.

Dunhevidia setigera Birge. Mexico City.

Pleuroxus denticulatus Birge. Mexico City.

Chydorus globosus Baird. Mexico City.

Chydorus sphaericus O. F. Mueller. Lakes Amatitlan and Atitlan, Mexico City, Puerto Barrios.

In his report on the fresh-water copepoda from Panama Marsh[1] states that the general character of the copepod fauna of the Canal Zone is much more closely related to the South American fauna than to that of North America. This, however, does not appear to be true of the copepod fauna of Guatemala and Salvador since it consists chiefly of North American forms. Among the Calanidae only one form, *Diaptomus marshi*, is so far known to be common to the fauna of Panama and that of Guatemala and Salvador.

I am greatly indebted to Mr. H. K. Harring for the identification of the various rotifers.

[1] Smithso. Miscel. Col., vol. 61, no. 3, 1913, 30 p., 5 pl.

TABLE II. *Observations on Dissolved Gases.*

The depth is given in meters, the temperature in degrees centigrade, and the gases in cubic centimeters per liter of water. The last column shows the per cent of saturation of the oxygen. In the free carbon dioxide a minus sign indicates that the water was alkaline, a plus sign that it was acid, and neut. that it was neutral to phenolphthalein. The degree of acidity or alkalinity is indicated by the number of cubic centimeters of carbon dioxide that would have to be removed or added to make the water neutral.

Lake Amatitlan, February 5, 1910.

Depth, meters	Temperature, degrees C.	Carbon dioxide		Oxygen	
		Free	Fixed	Cc. per liter	Per cent. of saturation
0	20.2	—3.34	32.28	5.88	89.8
5				5.93	90.5
10	20.1			5.70	86.9
15	19.8	—3.34	32.28	4.75	72.0
20	19.6	neut.	32.28	4.35	65.7
25		neut.	32.28	4.38	66.2
30		+1.67	32.28	3.63	54.8
34	19.6	+2.78	32.28	3.34	50.4

Lake Atitlan, February 12, 1910.

0	19.6	—2.23	37.84	4.55	68.7
5	19.4			4.43	66.7
10	19.3	—2.23	37.84	4.46	67.0
20	19.25			4.49	67.4
30				4.50	67.5
50	19.2	—2.23	37.84	4.40	66.0
75		—2.23	37.84	4.40	66.0
100		—1.67	37.84	4.40	66.0
150				4.37	65.7
200		—1.11	37.84	4.39	66.0
250		—1.11	37.84	4.15	62.2
285		—1.11	37.84	4.07	61.0
315	19.2	—1.11	37.84	4.03	60.4

Lake Ilopango, February 23, 1910.

0	26.2	+2.78	47.30	4.98	84.0
5	26.2			4.98	84.0
10	26.0			4.80	80.8
12.5	25.6			4.30	71.9
15	25.5			3.82	63.7
20	25.4			3.50	58.3
25	25.4	+2.78	48.41	3.34	55.6
50	25.4	+4.46	48.41	3.30	55.0
75		+5.00	48.41	3.15	52.5
100		+5.56		3.14	52.3
150		+6.67	48.41	3.08	51.3
180		+6.67	49.00	2.98	49.7
215	25.4	+7.23	49.53	3.05	50.8

TABLE II.—Continued

Lake Coatepeque, February 25, 1910.

Depth, meters	Temperature, degrees C.	Carbon dioxide		Oxygen	
		Free	Fixed	Cc. per liter	Per cent. of saturation
0	22.1	—5.57	55.65	5.15	81.2
10	21.8			5.40	84.7
20	21.7	—5.57	55.65	5.35	83.8
30	21.5	—4.45		4.81	75.1
50	21.2	—3.34	56.20	4.54	70.6
75	21.1	—3.23	56.76	4.38	67.8
95		—3.23	56.76	4.59	71.0
110	21.0	—3.23	56.76	4.49	69.5

Cayuga Lake, New York, August 11, 1910.

0	19.6	—2.5	22.2	6.65	100.4
5	19.6			6.85	103.5
10	19.6	—2.5	22.2	6.84	103.0
15	19.2	—2.5	22.2	7.00	105.0
20	11.5	—0.4	22.2	8.27	106.5
25	8.6	neut.	22.8	8.53	102.9
30	7.0	neut.		8.68	100.9
40	5.9	+0.1	22.8	8.80	99.6
50	5.1			8.93	99.1
75	4.5	+0.4		9.05	98.2
100	4.5	+0.7	23.3	7.92	86.6
120	4.4	+1.0	23.8	7.63	83.2

Seneca Lake, New York, August 3, 1910.

0	20.2	—2.5	22.0	6.85	104.6
5	20.0			7.00	105.7
10	19.0	—2.5	22.0	7.40	110.6
15	17.2			7.80	112.8
20	11.6	—1.0	22.0	8.40	108.4
30	8.3	—0.5	22.0	8.80	105.4
50	5.2			8.70	96.8
75	4.6			8.90	97.5
100		neut.	22.0	9.00	98.4
130		+0.2		9.10	99.2
150		+0.4	22.2	8.55	93.0
173	4.2	+1.2	22.2	8.45	91.7

TABLE III. *The Distribution of the Plankton Organisms.*

The verticle distribution of the various organisms is shown by giving the number of individuals per cubic meter of water in the different strata. The members grouped in the different columns are indicated as follows:

1. Cladocera, D. h.=*Daphnia hyalina*, D. p.=*Daphnia pulex*, C.=*Ceriodaphnia*, B.=*Bosmina*, Di.=*Diaphanosoma*, P.=*Polyphemus*, Ch.=*Chydorus*. 2. Copepods, D.=*Diaptomus*, L.=*Limnocalanus*, C.=*Cyclops*, N.=*Nauplii*. 3. Rotifera, A. a.= *Anuraea aculeata*, A. c.=*Anuraea cochlearis*, A. s.=*Anuraea stipitata*, N.=*Notholca*, S.=*Synchaeta*, P.=*Polyarthra*, Pl.=*Ploesoma*, A.=*Asplanchna*, C.=*Conochilus*, Tr.= *Triarthra*, Pe.=*Pedalion fennicum*, R.=*Rattulus*, Bd.=*Bdelloid rotifer*, B. p.= *Brachionus pala*. 4. Protozoa, C.=*Ceratium*, D.=*Dinobryon*, P.=*Peridinium*, M.= *Mallomonas*, T.=*Tintinnus*, V.=*Vorticella*. 5. Algae exclusive of diatoms, C.=*Clathrocystis*, Aph.=*Aphanizomenon*, A.=*Anabaena*, G.=*Gloeocystis*, Gl.=*Gloeocapsa*, Cl.=*Closterium*, S.=*Staurastrum*, Z.=*Zygnema*. 6. Diatoms, A.=*Asterionella*, C.= *Cyclotella*, F.=*Fragilaria*, M.=*Melosira*, S.=*Synedra*, T.=*Tabellaria*.

Lake Amatitlan, February 5, 1910.

Depth, meters	Cladocera	Copepoda	Rotifera	Protozoa	Algae exclusive of diatoms.	Diatoms
0-5	D. h. 14,400 C. 5,200 B. 4,200	D. 11,600 C. 11,400 N. 49,000	A. s. 300	C. 1,131,500 P. 201,500	G. 15,500 Cl. 403,000 S. 77,500 A. 15,500 C. 124,000	F. 15,500 M. 10,974,000 S. 93,000
5-10	D. h. 2,100 C. 900 Ch. 25 B. 500	D. 5,100 C. 3,500 N. 9,400	A. s. 200	C. 503,100 P. 15,500	S. 15,500 A. 23,200 C. 92,900	F. 10,200 M. 9,466,000 S. 247,700
10-15	D. h. 100 C. 300 B. 500	D. 2,200 C. 4,200 N. 5,900	A. s. 100 Pe. 100	C. 139,500 P. 12,500	S. 15,500 A. 15,500 C. 62,000	F. 15,000 M. 7,486,000 S. 620,000
15-20	D. h. 200 C. 100 B. 100	D. 1,200 C. 5,600 N. 4,300	A. s. 100 Pe. 800 Tr. 100	C. 23,200 P. 23,200	S. 46,400 C. 69,600	F. 23,200 M. 5,429,000 S. 719,200
20-25	D. h. 400 C. 300	D. 1,100 C. 4,300 N. 8,400	A. s. 100 Pe. 1,600	C. 23,200 P. 31,000	C. 54,200	M. 4,497,000 S. 294,000
25-33	D. h. 300 C. 70	D. 900 C. 6,600 N. 6,300	A. s. 300 Pe. 900	C. 29,000 P. 43,500	S. 14,500 C. 145,000	M. 5,118,000 S. 275,500

Lake Atitlan, February 11, 1910.

Depth, meters	Cladocera	Copepoda	Rotifera	Protozoa	Algae exclusive of diatoms	Diatoms
0-5		N. 250	B. p. 3.500		Z. 20,600 Gl. 20,600	F. 20,600 S. 20,600 M. 42,765,000
5-15	D. h. 8,600 Di. 90 C. 270 B. 6,320	C. 17,700 N. 3,250	A. s. 700 B. p. 6,500 P. 270			M. 46,061,000
15-30	D. h. 2,460 B. 160	C. 17,200 N. 3,250	A. s. 90 B. p. 12,700			M. 21,094,000
30-50	D. h. 100 B. 110	C. 3,800 N. 1,300	B. p. 3,300			M. 8,804,000
50-75	D. h 160 B. 110	C. 950 N. 1,370	B. p. 1,900			M. 7,490,000
75-100	D. h. 30 B. 30	C. 730 N. 950	B. p. 820			M.3,608,000
100-150	D. h. 470 D. p. 130 B. 260	C. 1,150 N. 300	B. p. 1,400			M. 4,315,000
150-200	D. h. 200 D. p. 640 B. 160	C. 1,100 N. 280	B. p. 1,000			M. 1,522,000
200-250	D. h. 190 D. p. 110 B. 70	C. 1,000 N. 180	B. p. 840			M. 1,531,000
250-310	D. h. 65 D. p. 20 B. 10	C. 320 N. 65	B. p. 140			M.1,031,000

Lake Ilopango, February 23, 1910.

0-10	B. 14 C. 14	D. 6,100 N. 400	Pe. 443,000	D. 600 Tin. 134,000		C. 1,240 S. 1,860
10-25	B. 20 C. 180	D. 12,900 N. 1,150	Pe. 27,200	Tin. 748,000		C, 10,200 S. 6,800
25-50	C. 30	D. 1,200 N. 1,440	A. s. 50 N. 50 Pe. 1,080	Tin. 29,000		C. 1,000
50-100		D. 110 N. 70	Pe. 170	Tin. 11,400		

Lake Ilopango, February 23, 1910.—Continued.

Depth, meters	Cladocera	Copepoda	Rotifera	Protozoa	Algae exclusive of diatoms	Diatoms
100-150		D. 20 N. 20	Pe. 55	Tin. 6,400		C. 380
150-215		D. 30 N. 50	Pe, 10	Tin. 5,900		

Lake Coatepeque, February 25, 1910.

0-10	C. 6,800	D. 121,200 N. 800	Bd. 27,100 Pe. 130	C. 15,300 Tin. 948,600	C. 23,200 Aph. 3,900	C. 7,700
10-25	C. 6,000	D. 66,000 N. 1,500	Bd. 40,800 Pe. 400	C. 7,700 Tin. 124,000	C. 45,900	C. 56,100
25-50	C. 300	D. 13,200 N. 2,750		C. 1,100 Tin. 51,000	C. 6,200	C. 595,000
50-75	D. h. 5 C. 30	D. 4,200 N. 1,700		C. 1,100 Tin. 51,000	C. 4,600	C. 858,400
75-110	D. h. 10	D. 1,950 N. 950		C. 1,100 Tin. 25,300	C. 2,200	F. 2,200 C. 1,315,600 M. 1,100

Cayuga Lake, New York, August 12, 1910.

0-5	B. 21,500 C. 260 P. 130	C. 1,200 N. 400	A. 200 A. c. 520 P. 239,900 S. 1,000	C. 1,648,600 D. 15,500 V. 8,800	A. 9,000 C. 1,000	A. 2,105,300 F. 812,700 T. 54,200
5-10	B. 32,700 C. 390	C. 260 D. 130 N. 650	A. 300 A. c. 650 P. 38,500 Pl. 130 S. 750	C. 960,000 D. 15,500 V. 650	A. 8,000 C. 7,700	A. 3,204,000 F. 928,800 T. 108,300
10-15	B. 30,500	C. 520 D. 1,600 N. 2,500	A. 170 A. c. 130 P. 12,600 Pl. 1,600 S. 350	C. 665,600 D. 15,500 V. 260	A. 7,700 C. 31,000	A. 2,182,700 F. 944,300 T. 123,800
15-20	B. 28,000	C. 260 D. 2,200 N. 19,200	A. 140 A. a. 130 A. c. 3,700 N. 130 P. 6,000 Pl. 910 S. 250	C. 270,900 D. 4,000 M. 116,100	C. 7,700	A. 1,509,000 F. 611,400 T. 201,000

Cayuga Lake, New York, August 12, 1910.

Depth, meters	Cladocera	Copepoda	Rotifera	Protozoa	Algae exclusive of diatoms	Diatoms
20-30	B. 2,300	C. 1,400 D. 790 N. 4,300	A. 100 A. a. 130 A. c. 1,580 N. 80 P. 60 Pl. 60 S. 200 T. 460	C. 73,500 D. 3,900 M. 31,000	C. 3,900	A. 569,000 F. 301,800 T. 104,500
30-50	B. 360	C. 720 D. 790 N. 1,200	A. a. 60 A. c. 130 N. 150 P. 2,100 Pl. 50 S. 250 T. 100	C. 7,600 M. 1,900	C. 3,500	A. 67,500 F. 23,100 M. 3,800 T. 27,000
50-75	B. 80	C. 640 D. 340 N. 1,000	A. a. 25 A. c. 25 N. 50 P. 630 Pl. 50 S. 150 T. 30	C. 10,800	C. 1,500	A. 41,800 F. 7,700 T. 7,700
75-100	B. 670	C. 80 D. 20 N. 60	A. c. 30 N. 30 P. 630 Pl. 50 S. 200 T. 30	C. 26,300	C. 1,500	A. 35,600 F. 20,000 T. 7,700
100-120	B. 60	C. 50 D. 100 N. 160	A. c. 90 N. 30 P. 180 S. 90 T. 90	C. 15,000 M. 1,900	C. 1,500	A. 30,900 F. 9,600 T. 15,200

Seneca Lake, New York, August 2, 1910.

0-10	B. 6,750 C. 60	C. 920 D. 260 N. 4,060	A. 2,060 A. c. 2,100 N. 60 P. 2,300 Pl. 1,450 R. 50 S. 2,000	C. 32,800 D. 1,900 V. 60	An. 1,900 C. 7,700	A. 135,000 F. 17,300 M. 1,900 T. 7,700
10-20	B. 8,060	C. 4,200 D. 1,300 N. 9,500	A. 50 A. c. 4,300 C. 250 N. 130 P. 2,300 Pl. 200 R. 100 S. 200	C. 73,300 V. 920	C. 17,400	A. 310,700 F. 5,800 T. 9,600 S. 1,900

Seneca Lake, New York, August 2, 1910.—Continued.

Depth, meters	Cladocera	Copepoda	Rotifera	Protozoa	Algae exclusive of diatoms	Diatoms
20-30	B. 1,050	C. 8,400 D. 3,800 N. 19,100	A. 220 A. a. 220 A. c. 1,120 C. 450 N. 220 P. 2,100 Pl. 100 R. 110	C. 9,600 M. 9,600	C. 5,800	A. 169,800 F. 9,600 T. 3,800
30-50	B. 140	C. 2,200 D. 3,400 N. 1,900	A. c. 200 P. 280 S. 30	C. 500	C. 1,000	A. 3,400 F. 1,000 T. 500
50-75	B. 25	C. 50 D. 820 N. 2,000	A. c. 70 P. 70	C. 500	C. 500	A. 1,000 F. 250 T. 250
75-100		C. 50 D. 250 L. 30 N. 750	A. c. 30 P. 130	C. 250	C. 700	A. 250
100-130		C. 40 D. 100 L. 20 N. 280	A. c. 20 P. 20	C. 600	C. 400	A. 200
130-165		C. 20 D. 150 L. 10 N. 400	A. c. 20 P. 40	C. 170	C. 850	A. 100 F. 500

NOTES ON PARASITIC FUNGI IN WISCONSIN—III.

Supplementary to *a provisional list of parasitic fungi in Wisconsin.* Trans. Wis. Acad. Sciences, Arts & Letters *17*:2:846–984.

J. J. Davis.

The fungus recorded in the provisional list under the name *Synchytrium decipiens* Farl. is referred to the chytridiaceous genus *Woroninella* by H. Sydow using the combination *W. aecidioides* (Pk.) Syd. (Ann. Mycol. *12*:5:484). Peck's original binomial was *Uredo aecidioides* which had been proposed previously for another fungus which fact has been held by some mycologists to invalidate the publication; hence the use of another specific name.

Oöspores occur in Wisconsin collections of *Plasmopara ribicola* Schroet. They are globose, brown, smooth, 33–36μ in diameter; endospore 3—4μ thick; oögonia 37—40μ filled by the oöspores.

Peronospora parasitica (Pers.) Tul. Guy West Wilson proposes the divisiòn of this into two species and a like treatment of *P. effusa* (Grev.) Ces. (Mycologia *6*:197 *et seq.*).

Peronospora trifoliorum D By., does not occur on clover in Wisconsin as far as observed even in fields where both *Trifolium* and *Medicago* are abundant and the latter infected. The conidia exceed the dimensions given for this species. I append measurements made from the conidia of two collections:

May 13, 1914.	May 25, 1914.
31 x 22μ	26 x 20μ
26 x 18	22 x 19
30 x 21	22 x 18
29 x 17	26 x 22
26 x 16	25 x 22
34 x 24	22 x 18
26 x 22	24 x 18
29 x 20	22 x 19
30 x 25	26 x 19
29 x 18	

These measurements indicate that the conidia were larger on the earlier date. The meteorological records show that May 13th was a day of low temperature and low relative humidity (44°–62°. 39–25) while on May 25 the temperature ranged 62°–84° and the humidity 99–66. I take it that to the low temperature may be credited the larger conidia on May 13th. This reminds one of Melhus' finding that a comparatively low temperature favors germination of conidia of *Peronosporales.*

During one season, somewhere in the 'nineties, there appeared at one station in the suburbs of Racine a destructive outbreak of *Erysiphe* on *Galium aparine.* On examination from time to time no spores were found in the asci and no specimens were preserved for that reason as I did not know at that time that they were not formed during the season. The mildew was looked for during subsequent years but was not again seen.

From an examination of specimens of *Lophodermium pinastri* (Schrad.) Chev. on *Pinus Banksiana* collected at Millston June 5, 1914, the following measurements were made: asci 115–185 x 22–30μ: ascospores 55–100 x 3½–4μ. It has been distinguished on the label in the herbarium as var. *amplum.* The affected leaves were still *in situ.*

Phyllosticta paviae Desm. is connected by V. B. Stewart with the ascigerous fungus *Laestadia aesculi* Pk. (Phytopath. *4*:399.)

Phomopsis vexans (Sacc. & Syd.) Harter is the name given by Harter to the fungus recorded in the provisional list under the name *Phyllosticta hortorum* Speg. (Journ. Ag'l Research *2*:338).

The *Septoria* which occurs on *Agrimonia* in Wisconsin bears smaller sporules than the *Septoria agrimoniae-eupatorii* Bomm. & Rouss. of Europe as described. They are usually 25–40 x 1μ.

There is considerable variation in the appearance of *Septoria* on *Echinocystis* in Wisconsin. The spots are commonly small, round and arid such as are attributed to *Septoria sicyi* Pk. and *S. brencklei* Sacc. Sometimes, however, they are angular, intervenular, green becoming brown. This is more nearly the kind of spot described under *Septoria echinocystis* E. & E. Both types of spot are sometimes found on the same leaf. Dr. R. A. Harper kindly compared a Wisconsin specimen with green to brown angular spots with the type of *Septoria echinocystis* E. & E. in the Ellis herbarium and wrote as follows: "The spores agree as to size etc. The spots in the type are larger, more brownish in color and rounded with a well defined center. It seems however that it ought to be the same thing." (*In lit.* Apr. 30, 1914) As these two kinds of spots intergrade I cannot consider them as due to specific distinctness of the infecting agents but rather as shade and moisture forms on one hand and the results of sunshine and dry air on the other, the latter conditions favoring a process of delimitation. As to the size of the sporules I find them to range from 20–60 x 1–2μ. In the form with round arid spots they are usually shorter than in the one with angular green-brown spots. For instance in a collection that could be referred to *S. brencklei* Sacc. most of the sporules are about 36μ long with an extreme length noted of 48μ. The collection of the *S. echinocystis* type from which a specimen was sent to Dr. Harper for the comparison has sporules 35–55 x 1–1½μ. There seems to be no reason as yet for changing the record of these forms from *Septoria sicyi* Pk.

The entry *Septoria stachydis* Rob. & Desm. in the Wisconsin lists seems to have been founded upon immature specimens of another fungus.

In returning a portion of the type specimen of *Septoria intermedia* E. & E. Mr. Ellis wrote as follows on the packet: "There was only one leaf; this is part of it. It seems to differ from *S. solidaginicola* in its shorter spores but it may turn out after all to be only a var. of the species'', and then by way of postscript, ''Try and look into it.'' I think that it is now safe to say that the name should be eliminated by reason of being applied to a short spored specimen of a *Septoria* that occurs in Wisconsin on both *Solidago* and *Aster* and known as *S. solidaginicola* Pk. According to the description the sporules of that species are 4μ in diameter while in our specimens they are $1\frac{1}{2}$–$2\frac{1}{2}\mu$. Through the kindness of Dr. H. D. House I have had an opportunity to examine type material and find the sporules about $1\frac{1}{2}\mu$ thick.

Examination of Wisconsin specimens that were referred to *Phleospora oxyacanthae* (Kze. & Schm.) Wallr. shows a fine branched mycelium, inter- and intra-cellular, ramifying through the affected portions of the leaves. The aerial branches of this mycelium constitute the conidia which are assurgent, more or less strongly curved sometimes even horse shoe shaped, pluriseptate, 60–100×4–5μ. These form a loose white felt in patches on the lower surface of the leaves which suggest a powdery mildew. No spots are caused but the affected tissues finally become dead and brown.

Leptothyrium dryinum Sacc. Specimens on *Quercus rubra* collected at Minocqua have sporules $15 \times 10\mu$ like those of *Leptothyrium maculicolum* Wint. but the small fruit bodies borne on large pale leaf areas are characters of *L. dryinum* Sacc. A specimen collected at Racine is probably on *Quercus ellipsoidalis. Quercus alba* should be stricken from the list of hosts of this fungus in the provisional list as I find that the specimen in my herbarium on that host is *Phyllosticta phomiformis* Sacc.

Gloeosporium septoriodes Sacc. Saccardo in his description states that the sporules are always continuous. Winter in his description of *Marsonia quercina* Wint. which Saccardo gives as a synonym, describes the sporules as uniseptate. Ellis & Everhart in their description of *Gloeosporium septorioides* Sacc. var. *major* E &. E. state that the endochrome is often indistinctly divided in the center. Wisconsin specimens on *Quercus rubra* show occasional sporules with a median septum and the two halves of the sporule separate at this point resulting in two independent sporules. Some of the sporules attain a length of 30μ.

Gloeosporium thalictri Davis. In specimens collected at Phlox the spots are larger (10–15 mm.) and sometimes less definite than in the type. They become sordid-arid above and the central portion falls away. The acervuli are light brown and amphigenous.

The fungus recorded in the provisional list under the name *Cylindrosporium leptospermum* Pk. was originally described as a *Cercospora* and the change, for which I was perhaps in some degree responsible, seems to me to have been ill advised. As I see it the fungus belongs in *Hyphales, Mucedinaceae, micronemeae, scolecosporae* and I know of no genus into which it fits.

As a result of inoculation experiment by B. B. Higgins the *Cylindrosporium padi* Karst. of the provisional list has been divided into three species and connected each with an ascigerous stage upon the fallen leaves the following spring. According to this classification our Wisconsin species would stand as follows:

Cylindrosporium hiemale Higgins
On *Prunus pennsylvanica*
cuneata
Cerasus (cult.)
Ascogenous state *Coccomyces hiemalis* Higgins.

Cylindrosporium prunophorae Higgins
On *Prunus domestica* (cult.)
Ascogenous state *Coccomyces prunophorae* Higgins.

Cylindrosporium lutescens Higgins.
On *Prunus serotina.*
virginiana

Ascogenous state *Coccomyces lutescens* Higgins. I assume that the fungus on *Prunus cuneata* is identical with that affecting other members of the host group. Inasmuch as the host of the typical *Cylindrosporium padi* Karst. is a member of the same group as are the hosts of *C. lutescens* Higgins the distinctness of the latter species is not established.

Ramularia dioscoreae Ell. & Evht. (Proc. Acad. Nat. Sci., Phila., 1891, p. 85) was founded upon leaves of *Smilax* bearing *Ramularia subrufa* Ell. & Hol. It is therefore to be elided.

Solidago ulmifolia where given as a host of *Ramularia virgaureae* Thuem. in the provisional list should be placed under *Ramularia serotina* E. & E. instead. *Ramularia virgaureae* Thuem. seems to vary from an *Ovularia* to a *Cercosporella* type.

Piricularia parasitica Ell. & Evht. When well developed the conidia are produced into long slender tips as in *Cercospora* and may attain a length of 50μ.

Fusicladium radiosum (Lib.) Lind. In the provisional list this combination was erroneously attributed to Lindr. I have assumed that this is a widespread and variable species which includes the fungus occurring in Wisconsin the conidia of which vary from 15–30 x 6–11μ. *Venturia tremulae* Aderh. in that case is the ascogenous state. Peck's description of his *Cladosporium letiferum* (40th Report, p. 64) applies very well to the fungus occurring in Wisconsin and I therefore take it to be a synonym. Quite different material was collected on *Populus tremuloides* at Pepin in August and referred to var. *microscopicum* (Sacc.) Allesch. The following notes were made from this material.

Spots 1–4 mm. in diameter, orbicular, sordid-arid above with a narrow, dark, raised margin, alutaceous below also with a dark margin and a central paler portion on which the conidiophores are borne; conidia continuous, 15–18 x 4μ. This differs from the variety, as described, in the narrower, continuous, hypophyllous conidia as well as in the character of the spots.

In the 4th supplementary list, p. 78, I gave notes of a specimen that I had referred to *Cercospora megalopotamica* Speg. To indicate something of the variation I add notes regarding two further collections: Spots suborbicular, definite, immarginate, blackish brown becoming paler with age and finally white in the center, 2–10 mm. in diameter; conidiophores tufted, septate, smoky brown, 55–80 x 4–5μ; conidia slender, straight, attenuate, pluriseptate, 60–125 x 3μ. On *Bidens connata,* Price County, Sept. 9th, 1911.

Spots suborbicular, light brown with a purple margin and a white center, paler and devoid of purple below, 4–8 mm. in diameter; conidiophores amphigenous, fasciculate, varying from subhyaline to brown, straight, flexuose or bent, continuous, entire or toothed, 15–45 x 3μ; conidia hyaline, straight, attenuate, pluriseptate, 60–100 x 3–4μ. On *Bidens connata,* Fountain City, August 12, 1914.

Telia of *Uromyces albus* (Clint.) Diet. & Hol. on leaves of *Vicia americana* were collected at Sharon in 1889. I am unable to perceive an arrangement of the verrucosities of the spore walls in rows.

The rust on *Hystrix patula* referred to *Puccinia apocrypta* Ell. & Tracy in the provisional list is probably *Puccinia impatientis* (Schw.) Arth. as I am informed by Dr. Arthur.

Gymnoconia peckiana (Howe) Trotter is made up of the aecial *Caeoma nitens* Schw. and the telial *Puccinia peckiana* Howe. Kunkel doubts the relationship (Am. Journ. Bot. *1*:37–45).

Telia of *Melampsoropsis cassandrae* (Pk. & cl.) Arth. were collected at Solon Springs, June 15th, 1914.

Additional Hosts.

Plasmopara australis (Speg.) Swingle. On *Echinocystis lobata.* Galesville.

Peronospora parasitica (Pers.) Tul. On *Cardamine bulbosa.* Madison.

Peronospora trifoliorum D By. On *Astragalus canadensis.* St. Croix Falls.

Peronospora chamaecysis Wils. is the species that has been formed to include American forms such as were recorded in the provisional list as *P. euphorbiae Fckl. (Mycologia 6*; 204). On *Euphorbia glyptosperma.* Trempealeau.

Sclerospora graminicola (Sacc.) Schroet. On *Setaria glauca.* Bridgeport.

Sphaerotheca humuli (D C.) Burr. On *Viola canadensis.* Clintonville. Abundant at this station but confined to the single species of violet. *Viola scabriuscula* was abundant but entirely free from the mildew.

Erysiphe polygoni DC. On *Delphinium* (cult.) Poynette. (H. L. Russell?)

Asterina rubicola Ell. & Evht. On *Rubus occidentalis.* Grant County, opposite Bridgeport.

Plowrightia morbosa (Schw.) Sacc. On *Prunus pumila.* Shore of Lake Superior in Ashland or Iron County. (L. S. Cheney.) A specimen in the herbarium of the University of Wisconsin, collected in 1896, appears to be on this host.

Phyllosticta minima (B. & C.) Ell. & Evht. On *Acer saccharinum.* Galesville.

Phyllosticta phomiformis Sacc. On *Quercus bicolor.* Alma. Apparently no one has referred this species to *Macrophoma.*

Phyllosticta decidua Ell. & Kell. What I take to be this fungus has been collected on *Hieracium aurantiacum* at Phlox.

Septoria alnifolia Ell. & Evht. On *Alnus crispa.* Vilas County.

Septoria dentariae Pk. On *Cardamine bulbosa.* Madison.

Septoria astericola Ell. & Evht. On *Aster Shortii.* Potosi. Sporules 22–33 x 1μ.

Septoria ribis Desm. On *Ribes nigrum* (cult.) Madison. This was collected in November and the triseptate sporules, as is often the case with conidia late in the season, show a tendency to divide at the septa.

Septoria sambucina Pk. On *Sambucus racemosa.* Neopit.

Septoria atropurpurea Pk. On *Aster sagittifolius.* Grant County opposite Bridgeport. On *Aster laevis.* Wyalusing. This has the dark purple spots with small central white areas but the sporules are 90–110μ long as in *S. punicei* Pk.

Phleospora ulmi (Fr.) Wallr. On *Ulmus fulva.* Richland Center (Harper & Reed). Maiden Rock. If *Phleospora ulmi* (Fr.) Wallr. is a conidial state of *Euryachora ulmi* (Fr.) Schroet. and the ascigerous condition in Wisconsin is distinct from this and is what is known as *Dothidella ulmea* (Schw.) E. & E. then the conidial state must be distinct also and should have another name. Rehm has replaced the generic name *Dothidella* Speg. by the older *Euryachora* Fckl. (Ann. Mycol. *6*:516). It would be best perhaps to designate the states as *Euryachora ulmea*

(Schw.) and *Septogloeum ulmeum.* Both the American and European specimens that I have seen have shorter sporules (often 30—40μ) than the description indicates and are variable.

Gloeosporium septorioides Sacc. On *Quercus rubra.* St. Croix Falls. In this collection the sporules are mostly 18–22μ long, continuous.

Gloeosporium caryae Ell. & Dearn. On *Carya cordiformis.* Trempealeau and St. Croix Falls. In these collections the acervuli are epiphyllous. This fungus received a second description under the same name by Ellis & Everhart, hence the citation of these authors in the provisional list.

Gloeosporium ribis (Lib.) Mont. & Desm. On *Ribes gracile.* Trempealeau.

Marssonina potentillae var. *tormentillae* Trail. On *Rubus triflorus.* Phlox. Subcuticular. Sporules 15–18 x 3–4μ. Also collected at Solon Springs.

Microstroma juglandis (Bereng.) Sacc. On *Juglans nigra.* Galesville.

Monilia fructigena Pers. On fruit of *Prunus virginiana,* Millston and *P. pennsylvanica,* Solon Springs.

Ramularia rosea (Fckl.) Sacc. On *Salix rostrata.* Alma. *Salix pedicellaris.* St. Croix Falls.

Ramularia pratensis Sacc. On *Rumex altissimus.* Maiden Rock. Conidia about 30 x 3μ continuous. Conidiophores mostly shorter.

Ramularia rufomaculans Pk. On *Polygonum scandens.* St. Croix Falls. Not abundant on this host.

Ramularia aequivoca (Ces.) Sacc. On *Ranunculus septentrionalis.* St. Croix Falls.

Piricularia grisea (Cke.) Sacc. On *Setaria viridis.* Bridgeport.

Passalora fasciculata (C. & E.) Earle. On *Euphorbia serpyllifolia.* St. Croix Falls.

Cercosport circumscissa Sacc. On *Prunus pennsylvanica.* Neopit.

Cercospora althaeina Sacc. On *Callirhoe triangulata.* Prairie du Chien and Grant County. The relationship to the form on *Althaea* is questionable. The conspicuous black-purple raised border of the spots in this collection give it a quite different appearance. I have labeled it var. *praecincta.*

Cercospora pentstemonis Ell. & Kell. On *Pentstemon grandiflorus.* Pepin.

Cercospora varia Pk. On *Viburnum acerifolium.* Devils Lake.

Uromyces acuminatus Arth. Aecia on *Steironema ciliatum.* Madison. But a scanty development on this host.

Uromyces proëminens (DC.) Lev. (*U. euphorbiae* of the provisional list). On *Euphorbia Geyeri* I, III, Pepin.
humistrata, III. Pepin.
heterophylla, III. Pepin.
The rust on the latter is *U. poinsettiae* Tranz. which is here considered a race.

Uromyces hyperici-frondosi (Schw.) Arth. Aecia, uredinia and telia on *Hypericum majus.* Devils Lake.

Puccinia andropogonis Schw. Aecia on *Pentstemon gracilis.* Millston.

Puccinia perminuta Arth. On *Agrostis perennans.* Alma.

Puccinia impatientis Arth. On Elymus canadensis glaucifolius. Maiden Rock.

Puccinia graminis Pers. Telia on *Calamagrostis canadensis.* Madison. (E. T. Bartholomew.)

Puccinia bolleyana Sacc. Aecia on *Sambucus racemosa.* Drummond. (L. S. Cheney)

Puccinia polygoni-amphibii Pers. Uredinia and telia on *Polygonum scandens.* St. Croix Falls. Uredinia on *Polygonum acre leptostachyum.* Madison.

Phragmidium disciflorum (Tode) James. (*Ph. americanum* (Pk.) Diet.) On *Rosa humilis.* Gaslyn and St. Croix Falls.

Pucciniastrum agrimoniae (Schw.) Tranz. Uredinia on *Agrimonia mollis.* Prescott and St. Croix Falls.

Uredinopsis atkinsonii Magn. Primary uredinia and telia on *Aspidium noveboracense.* St. Croix Falls.

In the provisional list no aecia on *Pinus* were recorded save an undetermined *Peridermium* on leaves of *Pinus Banksiana.* This was not because of the absence of such rust forms from the state, but because field work had not been done in the proper regions at the proper time to detect them. Since the list was prepared, however, some attention has been given them, the results of which it may be of interest to summarize.

The leaf *Peridermium* on *Pinus Banksiana* was collected in July 1907, near Gordon, Douglas County, and at Spooner, Washburn County. It is presumably connected with *Coleosporium* but has not been observed since. *Peridermium cerebrum* Pk. occurs throughout the range of *Pinus Banksiana* in the state and is quite abundant in some localities. Its effects are serious only when the infections are multiple or when it attacks the axis. The distribution of *Peridermium pyriforme* Pk. is also probably coextensive with the range of *Pinus Banksiana* in the state it having been collected in Jackson, Douglas and Vilas Counties, but it appears to be very sparsely distributed. In June, 1914, when special attention was given to it, no more than one specimen was collected in any locality. If this is connected with *Cronartium comandrae* Arth. it is not nearly so abundant or widespread as the telial form. *Peridermium comptoniae* Orton & Adams on the contrary, while it has been observed only in Douglas and Vilas Counties, occurs in considerable abundance both as to number of trees attacked and the extent of the outbreak on the individual tree. As I have seen it this usually occurs on the trunk near the base while *Peridermium pyriforme* Pk. I have seen only on branches. This is contrary to the statement of Arthur & Kern (*Mycologia 6*:132). Besides its native host, *Pinus Banksiana,* this rust attacked the young trees of *Pinus ponderosa* in the plantation of the Board of Forestry in Vilas County with severity; a severity due in large measure, doubtless, to the fact that the rust does not occur in the native habitat of this host and hence there has been no breeding out of susceptibility. Of the European *Peridermium fischeri* Kleb. which became thoroughly established on *Pinus sylvestris* in Door County, I have written elsewhere. It is hoped that with the destruction of the alternate host, *Sonchus,* this will disappear from the state. On our more valuable species of pine, *Pinus Strobus* and *P. resinosa,* no rust has been observed in Wisconsin, and it is hoped that none will be introduced.

Filamentous processes from base to apex of the peridium occasionally occur in *Peridermium comptoniae* Orton & Adams.

Aecidium maianthae Schum. On *Maianthemum canadense.* Solon Springs. This is probably the aecial stage of the rust on *Phalaris arundinacea* that was recorded under the name *Puccinia sessilis* Schn. in the provisional list. While collecting it a single sorus, but a well developed one, was found on *Streptopus roseus.* Under similar circumstances I once found a single sorus on *Habenaria hyperborea.* Such occurrences seem significant as to the relation of the segregates from *Puccinia sessilis* Schn. This was erroneously given the name *Aecidium smilacinae* Schum. in the provisional list.

Aecidium ranunculacearum DC. In small quantity on *Ranunculus abortivus* at Solon Springs where it occurred abundantly on *Anemone quinquefoila.* The infection of the former host seems to be very exceptional.

ADDITIONAL SPECIES.

Not reported in the Wisconsin lists.

Uncinula parvula Cke. & Pk. On *Celtis occidentalis.* Madison.

Exoascus betulinus (Rostr.) Sadeb. On *Betula alba papyrifera.* Solon Springs. This was seen on but a single tree and confined to a single branch.

Exoascus communis Sadeb. On fruit of *Prunus cuneata.* Millston, Solon Springs and Boulder Junction. Abundant in the former locality in 1914. Exceptionally this attacks petioles and young leaves which are deformed thereby.

Taphrina flava Farl. On *Betula alba papyrifera.* Ellison Bay. I am indebted to Dr. Farlow for authentic material of this species for comparison. My notes of the Wisconsin collection were as follows: Affected areas subcircular, indefinite, yellowish becoming brown below, light green above, about ½ cm. in diameter, sometimes confluent; asci hypophyllous, broad and truncate or somewhat rounded at base, obtusely rounded at apex, often more or less constricted in the middle, 30–36 x 18–26μ. No stalk cell is produced. The constriction of the asci appears to be caused by the pressure of the encircling edge of ruptured cuticle and to be greater when the asci are scattered.

Phyllosticta populina Sacc. On *Populus deltoides*. Prescott. The light grey spots are circular to subcircular with a narrow brown margin, 4–8mm. in diameter. It was associated with a *Septoria*.

In Ellis & Everhart's "The North American Phyllostictas" under *Phyllosticta grossulariae* Sacc. reference was made to Wisconsin material on *Ribes floridum* (= *R. americanum*) but it appears not to have been placed in my herbarium and was not recorded in the provisional list. I have found it on *Ribes vulgare* (cult.) at Fountain City accompanying *Cylindrosporium ribis* but mostly immature.

Phyllosticta crataegi (Cke.) Sacc. On *Crataegus*. Maiden Rock. This appears to be very close to what has been called *Phyllosticta destruens* Desm. on *Prunus virginiana* and *Amelanchier*.

Vermicularia liliacearum West. Specimens on leaves of *Streptopus roseus* appear to be parasitic as one might perhaps expect from the relation of this fungus to *Colletotrichum* by reason of its imperfect pycnidia. The sporules are narrow (3–4μ) in this collection.

Placosphaeria punctiformis (Fckl.) Sacc. On *Galium boreale*. Bridgeport. The spermogonial state of *Pseudopeziza repanda* (Fr.) Karst.

ASCOCHYTA MARGINATA n. sp. Spots circular to subcircular, 5–15 mm. in diameter, at first green becoming brown with a paler central portion and a darker periphery and a distinct narrow margin; pycnidia epiphyllous, scattered, pale brown, irregularly globose, about 100μ in diameter with a thin cellular wall and a dark ring around the pore; sporules hyaline, ovoid to oblong with rounded ends, some of them uniseptate, 6–12 x 2–3½μ.

On *Aralia nudicaulis*. Phlox, Wisconsin, July 11, 1914. The smaller and continuous sporules are probably immature but are in the majority in the material examined. There is evidence that the affected tissues fragment and fall away, for the most part probably, before the full maturity of the fungus.

A collection on leaves of cultivated *Phlox* made at Racine, Oct. 1, 1896, should probably be referred to *Septoria phlogis* Sacc. & Speg. The spots have no colored border; the epiphyllous pycnidia are delicate; the sporules range from 25–75 x 1–1½μ. Apparently the spots are brown and angular at first becoming white or sordid and more rounded in outline with maturity.

More or less of the distal portion of the leaves of *Carices* in Wisconsin are often observed to be dead and on examination scattered pycnidia are found. Specimens showing hyaline guttulate sporules 10–13 x 2½–3μ were referred to *Phyllosticta caricis* (Fckl.) Sacc. in the provisional list. Of a collection on *Carex sp. indet.* at Racine it was noted "sporules 10–13 x 3–5μ mostly becoming uniseptate; some of the sporules germinate without forming a septum." A collection from Gaslyn on *Carex pennsylvanica* bears 1–2 septate sporules 15–16 x 4μ; one from Spooner on *Carex intumescens* has biseptate sporules 16 x 4μ; one from Oakwood on *Carex sp. indet.* shows 1–2 septate sporules 12–18 x 4–5μ while in a collection on *Carex pennsylvanica* made at Neopit the sporules are 18–26 x 4–5μ, 3–4 septate. These seem to me to represent various degrees of maturity and development of a single fungus which is perhaps *Stagonospora caricinella* Brun. The Neopit collection bears also a *Septoria* having pycnidia about 100μ in diameter which contain sporules 37–55 x ½–1μ.

A specimen on *Carex retrorsa* collected at Athelstane agrees with the description of *Stagonospora paludosa* (Sacc. & Speg.) Sacc.

Septoria acerella Sacc. On *Acer Negundo*. Galesville. This agrees with the description given by Dr. Martin in "Septorias of North America". (Journ. Mycol. *3*:79.)

Septoria lophanthi Wint. On *Agastache scrophulariaefolia*. St. Croix Falls. In these specimens the sporules vary in length up to 80μ.

SEPTORIA CYLINDROSPORA n. sp.

Pycnidia scattered, black, globose to lenticular with cellular walls, 125–200μ in diameter; sporules hyaline, cylindrical, straight or slightly curved, 18–30 x 2–3μ. On calyces, bracts, leaves, and upper part of stems (especially on the south side) of *Pedicularis canadensis.* Solon Springs, June 1914. Under iodine the sporules show a median division. I have not seen *Rhabdospora sceptri* Karst. of which this may be only a form differing in the straight cylindrical sporules. This might be referred to *Ascochyta.*

Septoria xanthiifolia Ell. & Kell. On *Iva xanthifolia.* Alma.

Phleospora celtidis Ell. & Mart. On *Celtis occidentalis.* Wyalusing. In this collection the sporules attain a length of 100μ or more and become 8 or more septate.

Gloeosporium trifolii Pk. On *Trifolium pratense.* Minocqua. Abundant at one station.

Colletotrichum graminicolum (Ces.) Wilson. On leaves of *Echinochloa crusgalli.* Devils Lake. Setae 50–100 x 5–6μ, sporules 16–24 x 3½–6μ. Collected also at Alma and Maiden Rock.

COLLETOTRICHUM SORDIDUM n. sp.

Spots on the upper surface of the leaves varying from orbicular to irregular, light brown with a darker margin, 5–15 mm. in diameter to indefinite and more or less confluent into indefinite areas, cinereous above from loosened cuticle, on the lower leaf surface indefinite; acervuli epiphyllous, scattered, small, flat; sporules hyaline, cylindrical with rounded ends, straight, 21–33 x 6μ; setae dark brown to black, mostly incurved, 50–75 x 3–6μ with a septum near the base below which the seta is abruptly dilated. The affected portions of the leaves become quite friable. On *Menispermum canadense,* Wisconsin river bottom opposite Bridgeport, July 31, 1914. As there is a possibility that this may connect with *Gloeosporium sordidum* Speg. of South America I have used the same specific name.

Didymaria astragali (Ell. & Hol.) n. comb. (*Ramularia astragali,* Ell. & Hol.) On leaves of *Astragalus canadensis.* St. Croix Falls.

Ramularia spiraeae Pk. On *Physocarpus opulifolius*. Maiden Rock. Also observed at Dresser Junction, but too late in the season to secure good specimens.

RAMULARIA IONOPHILA n. sp.

Spots at first indefinite, green, angular, becoming suborbicular to irregular and more definite but not margined; conidiophores hypophyllous, hyaline, fasciculate from a more or less prominent stromatic base, straight or somewhat bent, continuous, 25–55 x 3–4μ; conidia hyaline, apical or subapical, cylindrical, straight, 1–3 septate, 18–45 x 3–4μ. On *Viola canadensis* Phlox, Wisconsin, July 1914. It may be that more knowledge of the Ramularias occurring on violets will bring together this and several other described species. The apex of the conidiophore frequently grows beyond the point where the conidium is borne.

CERCOSPORELLA SCIRPINA n. sp.

On elongate brown areas which become confluent; conidiophores in small tufts disposed in long intervenular lines, hyaline, continuous, subulate to cylindrical, often bent and denticulate above, 15–22 x 4–7μ; conidia hyaline, straight or curved, obclavate- cylindrical, obscurely septate, 50–122 x 3μ. On leaves of *Scirpus pedicellatus*. St. Croix Falls, August 25th, 1914.

CERCOSPORELLA FILIFORMIS n. sp.

Spots linear, brown, immarginate, ½–4 cm. x 1–2 mm.; conidiophores amphigenous, fasciculate, hyaline, continuous, somewhat lax, 10–15 x 1–2μ; conidia apical, filiform, hyaline, more or less curved and lax, sometimes pseudoseptate, 30–75 x 1–2μ. On leaves of *Anemone patens* var. *Wolfgangiana*. Millston, Wisconsin, June, 1914.

CERCOSPORELLA TRICHOPHILA n. sp.

Effused over indefinite areas on the lower surface of the leaves which are not discolored; mycelium hyaline, superficial, repent and ascending the trichomes; conidiophores racemose on the hyphae, hyaline, cylindrical to nodulose, straight, often oblique or denticulate at the apex, 10–15 x 3–5μ; conidia hyaline, obclavate-cylindrical, curved, pluriseptate, 45–75 x 3μ. On *Fraximus pennsylvanica*. Bridgeport, Wisconsin, August 1914. The conidiophores and conidia develop especially on the trichomicolous hyphae. The leaf surface becomes dotted with black, globose to hemispherical, sclerotioid bodies apparently connected with the same mycelium. Macroscopically this fungus suggests a young *Erysiphea*. Its systematic position is not clear.

CERCOSPORA CAMPTOSORI n. sp.

Spots subcircular to angular, pale brown becoming dark brown with age, immarginate, 3–7 mm. in diameter; conidiophores amphigenous, more or less fasciculate, brown, usually undulate, nodulose or bent, sometimes 1–2 septate, 18–57 x 3–4μ; conidia hyaline, obclavate-cylindrical to flagelliform, straight, 40–100 x 3μ. On *Camptosorus rhizophyllus*. Marquette State Park, Grant County, Wisconsin. August 1st, 1914. This differs from *Cercospora phyllitidis* Hume, as described, in the shorter conidiophores.

Cercospora muhlenbergiae Atk. On *Muhlenbergia sylvatica*. Kenosha County.

Cercospora comandrae Ell. & Dearn. On *Comandra umbellata*. Trempealeau. Curved and nodulose conidiophores are not infrequent.

Cercospora sanguinariae Pk. On *Sanguinaria canadensis*. Phlox.

CERCOSPORA ERYSIMI n. sp.

Spots pallid, subcircular, 3–5 mm.; conidiophores amphigenous, fasciculate, fuligineous, simple, straight or somewhat incurved, 30–55 x 3–4μ; conidia straight, obclavate, fuligenous tinted, about 5- septate, 45–75 x 3–4μ. On leaves of *Erysimum cheiranthoides*. Alma, Wisconsin, August 13th, 1914.

Cercospora condensata E. & K. On *Gleditsia triacanthos*. Marquette State Park near Wyalusing. Conidia up to 110μ in length were noted.

Cercospora negundinis Ell. & Evht. On *Acer Negundo*. Galesville and Alma. In this collection the conidia are hypophyllous; the conidiophores range to 40–50μ and the conidia to 150μ in length. As many as 9 septa have been observed in the latter. The conidiophores are mostly scattered or in twos and threes. Also collected in Grant County with amphigenous conidia and at Bridgeport.

CERCOSPORA CORNI, n. sp.

Spots indefinite, pale brown, becoming mottled with purple especially above; conidiophores hypophyllous, scattered, erect or ascending, brown, septate, 25–40 x 5–7μ; conidia apical, obclavate, bright brown, strongly pluriseptate, 70–160 x 5–7μ. On leaves of *Cornus paniculata.* St. Croix Falls, Wisconsin, August 31st, 1914. The conidiophores sometimes spring from the arch of a superficial mycelium and are then shorter. The affected areas which are mostly ½–1 cm. in diameter finally become dark and dotted with small, black, globular, sclerotioid bodies which are perhaps young pycnidia or perithecia.

CERCOSPORA ARCTOSTAPHYLI n. sp.

Spots circular, definite, sordid-arid with a narrow purple border, sometimes confluent, 2–5 mm.; conidiophores epiphyllous, springing mostly from small, dark tubercles, subhyaline, straight, erect, 7–15 x 3μ; conidia straight or slightly curved, acute, 30–50 x 1–1½μ. On *Arctostaphylos Uva-ursi.* Millston, Wisconsin, June, 1914.

Cercospora echinocystis Ell. & Mart. On *Echinocystis lobata* and *Sicyos angulatus.* Maiden Rock. In these specimens the conidiophores are scattered rather than fasciculate. Conidia up to 185 x 4μ were measured.

Cercospora effusa (B. & C.) Ell. & Evht. (?). On *Lobelia siphilitica.* Alma. In this collection the lax, nodulose, tortuous, septate conidiophores are 75–150μ long; the conidia 30–45μ long, triseptate, becoming brown and constricted at the septa when old. *Cladosporium effusum* B. & C. was said to occur on *Polygonum punctatum, Lobelia puberula* and *L. siphilitica* and *Nabalus altissimus* but Berkeley stated that he had seen conidia only on *Polygonum* and that they are curved which is not true of the fungus referred to here. On *Fungi Columbiani 2505* (on *Lobelia inflata*) I find conidia like those in the Wisconsin collection and also a few slender obclavate ones nearly 100μ long. That the latter were borne on the conidiophores I cannot say. The *Fungi Columbiani* specimen examined appears to bear a parasite producing small rod-like sporules in pycnidia. The conidiophores of the Wisconsin collection give off a few branches at or near a right angle.

Cercospora ageratoides Ell. & Evht. On *Eupatorium urticaefolium*. Galesville. In this collection the tufts are scattered over indefinite, but slightly discolored, spots.

Cercospora grindeliae Ell. & Evht. On *Grindelia squarrosa*. St. Croix Falls.

Cercospora absinthii (Pk.) Sacc. I am using this name to record the occurrence of a Dematiaceous fungus on leaves of *Artemisia ludoviciana* at St. Croix Falls regarding which the following notes were made: conidiophores amphigenous, scattered or in tufts of 2–6, more or less flexuous, pluriseptate, brown or olivaceous, 90–160 x 4–7μ; conidia apical, obclavate to obclavate-cylindrical, fuligineous tinted, developing about 4 septa, 30–50 x 4–6μ. The affected leaves show at first brown spots which become confluent into brown areas. The scattered distribution of the conidiophores and the wooliness of the leaves make this quite inconspicuous.

Uromyces astragali (Opiz) Sacc. I am using this name for the purpose of recording the occurrence of uredinia on *Astragalus canadensis* at St. Croix Falls. That this American rust is conspecific with the European one having its aecia on *Euphorbia Cyparissias* is questionable. The Sydows in *Monographia Uredinearum* state that it is not while Arthur in *North American Flora* refers it to that species under the synonym *Nigredo pustula* (Schroet.) Arth. (*Uromyces pustulatus* Schroet.) together with the *Uredo* on *Oxytropis* that has been known as *Uredo oxytropidis* (Pk.) De Toni. The statement of the Sydows that the uredospores on *Astragalus* in North America have 6–8 germ pores is not borne out by this material in which the pores are 3–4.

Aecidium lupini Pk. On *Lupinus perennis*. Millston. I am indebted to Dr. J. C. Arthur for the determination. In the 4th supplementary list mention was made of the occurrence of *Tuberculina persicina* (Ditm.) Sacc. on *Lupinus perennis* as evidence that the host bears an *Aecidium* in Wisconsin which however was not collected until 1914.

Aecidium liatridis Ell. & And. On *Liatris scariosa*. Solon Springs.

University of Wisconsin Herbarium, Madison, Wisconsin, April, 1915.

INDEX TO HOSTS MENTIONED IN "NOTES" III.

SOME OBSERVATIONS CONCERNING THE BOTANICAL CONDITIONS ON THE GALAPAGOS ISLANDS.

By Alban Stewart.

Introduction.

When I began the study and identification of the vascular plants of the Galapagos Islands at the Gray Herbarium, some seven years ago, I intended to include all of the results in a single publication. After I had completed that part of the work included in my paper entitled: A Botanical Survey of the Galapagos Islands* it was found that such a mass of manuscript had accumulated that it would probably be better to publish this part, and to reserve the general consideration of the floras of the individual islands for a separate publication.

An attempt has been made in this paper to describe briefly, and in a general way, the botanical conditions as I saw them upon each of the islands visited. No attempt has been made, however, to describe the floras of the different islands in a detailed way, because, such a consideration would consume too much space, and furthermore, as our stay in some of the localities visited was very brief, there was not sufficient time available to make a sufficiently detailed study of the flora for this purpose. This is especially true in some of the larger islands, where we were obliged to get as far into the interior as possible in a short time, hurriedly collect material, with brief notes, and then start back to the shore. Expeditions into the interiors of most of the larger islands are extremely difficult to make. Not only is the country very rough in most places, and covered with heavy vege-

* Proc. Cal. Acad. Sci., fourth series, vol. I, pp. 7–288. 1911.

tation, but there is also no water on the most of them; which makes it necessary for one to carry a supply of water with him. On this account it is practically impossible to make trips into the interior lasting longer than three days.

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Abingdon Island.

With the exception of the two small islands, Culpepper and Wenman, Abingdon is the most northern island in the group. It is located about thirteen miles northwest of Blindloe, and is the smallest one of the islands that supports an extensive mesophytic flora. This condition is brought about by the fact that it reaches an elevation of 1950 ft., and consequently it receives a greater amount of moisture than the other small islands. This island was visited during the month of September 1906. The most of the work was done on the south side where good anchorage was found for our vessel in a small bay.

The shores along the south side of the island are composed of low lava cliffs and occasional sand-beaches. The shores become steeper, however, towards the southwest side. On the west side there are perpendicular cliffs which rise directly from the sea to a height of over 1,000 ft. The north and east sides of the island were not visited, but judging from the appearance of these parts as seen from the vessel while sailing in the vicinity of the island, the shores are low, and the sides of the mountain are covered with lava to a considerable elevation. The lava covering the south side is mostly basaltic in character with occasional beds of volcanic cinders intermingled. This lava is of comparatively great age, and it has become stained to a redish-brown color through surface oxidation. There are extensive deposits of volcanic cinders on the southeast side of rather recent origin, the most of which have come from a small crater at an elevation of 1,000 ft. There are still slight evidences of volcanic activity around the base of this crater, as there is a constant escape of steam here, which is sometimes great enough to be seen from the shore. There is still another small cinder cone on the recent lava near the shore, from which the lava in its immediate vicinity must have come. Remains of several other small craters occur on the old lava around an elevation of 500 ft., all of which have probably been inactive for a very long time. The lava on the south side has been thrown into ridges and folds in places, and there are also occasional lava tunnels the tops of which have fallen in. One of these is located near the shore and is filled with sea water. The south side of the island slopes up gradually to an elevation of about 500 ft., above which the slope is steeper.

The top of the mountain was envelloped in fog at the time it was visited so that a survey of the surrounding region could not be made. There seemed to be no central crater present, however, and the highest part may be the remains of a portion of the rim. There is a range of hills, about two miles west of the summit, which runs parallel with the coast line, and have an elevation of about 1,200 ft. These hills rise abruptly from a broad, flat plain just east of them, which has an average elevation of 900 ft. It is possible that this plain may be the floor of an old crater, the rim of which has been mostly removed.

A few herbaceous halophytes grow on the sand beaches near where we anchored. There was also a low thicket of bushes of Laguncularia racemosa bushes growing here. Other than these no halophytes were found.

All of the vegetation of the south and southeast sides of the island below an elevation of 450 ft. consists of species which are usually found on the lower and dryer parts of these islands. They are smaller and fewer in number, however, than is usually the case, a condition that may be due to the very scanty soil on these parts. The lava on this part of the island is bare in most places, and the only soil to be found is in the lava crevices. In consequence of this condition, a large part of the surface is not suitable at present for the support of higher plants. The trees of Bursera graveolens are small, seldom exceeding a height of 8 ft. Usually they are mere bushes. Besides the small Bursera trees, Opuntia galapageia is the only other species which reaches the size of a tree in these lower regions. It occurs here abundantly, and has weak spines and closely arranged branches. Euphorbia viminea forma castellana is the most common bush in this region. It is about the only one that occurs in mass, all other bushes being scattered. This species seems to be better adapted to maintain an existence under the sterile conditions than most of the other species found here. Other bushes found growing in this region, less abundantly than the above are: Cordia lutea, Castela galapageia, Croton Scouleri var. brevifolius, Euphorbia articulata, Prosopis dulcis, Scalesia Hopkinsii, Telanthera echinocephala, and Waltheria reticulata. The lava ridges are often found to be more or less covered with vines of Ipomoea Habeliana, and in various other places on the lava, I. Kinbergi was found growing and in blossom at the time of our visit. Such grasses as Aristida suspicata, Cenchrus platyacanthus, Leptochloa albemarlensis and L. Lindleyana grew with more or less abundance in the lava crevices. On the older beds of volcanic cinders there was very little vegetation other than occasional bunches of Cereus nesioticus; the more recent beds of cinders were bare.

A change, readily noticed, takes place in the vegetation at about 450 ft. elevation evidently brought about by the greater amount of moisture and a more abundant soil. There is a general thickening up and an increase in the size of the vegetation above this elevation. There are good sized trees of Bursera graveolens in this region, and also trees of Pisonia floribunda, which first make their appearance. Many of the trees and bushes, at this elevation and above, are heavily covered with Alectoria sarmentosa and other epiphytic lichens. Bushes and small trees of Zanthoxylum Fagara also occur, usually infested with Phoradendron Henslovii. Other bushes which occur in this region and a little higher are: Chiococca alba, Erigeron tenuifolius, Lipochaeta laricifolia, and Lippia rosmarinifolia. Such ferns as Chelianthes microphylla, and Polypodium squamatum occur. Very little change takes place in the vegetation on the southwest side of the island below an elevation of 700 ft., probably due to the fact that this side receives less moisture than the south and southeast sides.

Practically all of the plants which occur below 500 ft. disappear by the time an elevation of 1,000 ft. is reached. The species that continue into this region from below, are, for the most part, those which first appeared around an elevation of 500 ft. and above. The region between 1,000 and 1,650 ft. elevation is covered with forests, on the southeast side, which are made up mostly of Pisonia floribunda, and Zanthoxylum Fagara. There is much undergrowth in these forests, consisting of bushes of Croton Scouleri var. grandifolius, Erigeron tenuifolius, Lippia rosmarinifolia, Psychotria rufipes, Scalesia Hopkinsii, Tournefortia psilostachya, and T. rufo-sericea, many of which are covred with vines of Cissampelos Pareira, and Elaterium cordatum. There are also many ferns among which are: Adiantum Henslovianum, Asplenium cristatum, Nephrolepis biserrata, Polypodium pectinatum, P. squamatum, and Trachypteris pinnata. Many herbaceous plants also occur in this region.

There are open areas in the vegetation on the south side of the island between 1,000 and 1,300 ft. elevation, which are covered with grasses and herbaceous plants. These areas extend in a more or less direct way up the side of the mountain, and are bordered by bushes which are heavily covered with a growth of brown Hepatic, probably a species of Frullania. These areas are succeeded above by a heavy growth of bushes and small trees.

Above 1,650 ft. elevation, extending to the top of the mountain, there is a heavy growth of ferns which are often five feet or more in height. Among the ferns there are low stunted bushes of Zanthoxylum Fagara heavily covered with epiphytes.

The dry region* on this island extends to about 450 ft. on the southeast side, and to about 700 ft. elevation on the southwest side. Judging from the appearance of the vegetation as seen from a distance, this region must extend to an elevation of about 1,000 ft. on the north side. The transition region extends to an elevation of about 1,000 ft. on the south and southeast sides, and probably to within a short distance of the top of the north side. There is apparently but a narrow strip near the top, on this side of the mountain, that is covered with dark green vegetation, such as is usually found in the moist region of these islands. All of the country above an elevation of 1,000 ft. is covered with the plants usually found in the moist regions.

Albemarle Island.

Albemarle lies towards the west side of the archipelago and is the largest island of the group. It is about seventy-five miles long, and forty-five miles broad at its widest part, which is towards the southern end of the island. The island has the general shape of the letter L the long limb of which extends in a general northwest and southeast direction. There are five large

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* For a discussion of the botanical regions on these islands see: Stewart, A Botanical Survey of the Galapagos Islands. Proceedings of the California Academy of Sciences, fourth series, vol. I, pp. 206–211. 1911.

mountains on the island which vary in height from 3,150 to probably over 5,000 ft., and several mountains of lower altitude. All of the larger mountains are extinct volcanoes each of which has an immense crater at its top. These craters are all inactive at the present time except the one northwest of Villamil, on the south side of the island, Sulphur fumes and other vapors issue from the floor of this crater at times, and there are also two small active sulphur volcanoes in it, each of which is surrounded by a large quantity of almost pure sulphur. There has been some volcanic activity at Banks Bay during the last few years, from small craters on the west side of the mountain. With these exceptions there has probably been no volcanic activity of the island for a great many years. There are many low hills on various parts of the island, some of which are small craters or blowholes, and others simply masses of volcanic debris.

Banks Bay.

Banks bay is a broad, open roadstead on the west side of the island, near its northern extremity. The main mountain at this place is a broad flattopped crater with steep sides, which probably rises to a height of over 5,000 ft. There is still a smaller mountain close to the north shore of the bay that has an elevation of 2,360 ft. according to the chart issued by the Hydrographic Office. There are also a number of smaller craters and hills around the base of the main mountain, and along it sides, which usually have an average height of less than 100 ft. The base of the main mountain is separated from the shore by a broad plain which is covered with beds of comparatively recent lava on which there is very little vegetation. There are places, however, on this plain which were not covered by the more recent flows of lava, on which there is a considerable amount of xerophytic vegetation.

Unfortunately this region was not explored botanically, so that all of the information concerning its flora is due to the kindness of other members of the expedition who visited this place. At least three botanical regions are represented here, viz.: the dry, transition, and moist regions, and possibly a fourth, as the vegetation around the top of the mountain appeared from a distance to be quite different from that lower down. With the exception of the transition, no estimate was made concerning the extent in elevation of these regions.

The shores support many of the smaller halophytic plants found on these islands, and "large mangroves", probably Laguncularia racemosa, and Rhizophora Mangle, occur abundantly in places. The older lava around the base of the mountain is covered with forms usually found in the dry regions. There are occasional specimens of an arborescent Cereus, and a low species of Opuntia occurs abundantly around the base, and on the sides of the mountain to an elevation of 1,600 ft. The trees in the lower regions are mostly of Erythrina velutina and Bursera graveolens, the last one of which was found to extend up to an elevation of 1,700 ft. on the side of the mountain. Many bushes and shrubs occur on the lower parts, but with the exception of Lipochaeta laricifolia, the names of these are not known. They are probably all of species usually common on the lower parts of these islands. Beds of "maidenhair fern", probably Adiantum Henslovianum, were found in a lava cavern at the base of the mountain. All together six species of ferns were noticed on this part of the island, but it is very likely that many more could be found if careful collecting were done in this region. Croton bushes are abundant, and occur to an elevation of 2,300 ft. as high as this mountain was explored by the members of the party who visited this part of the island. A "broad-leaved variety of Croton", probably C. Scouleri var. grandifolius, occurs high up on the side of the mountain, and "small-leaved varieties of Croton" occur around its base. There are one or more flows of recent lava down the west side of the mountain which are bordered by a heavy growth of bushes and morning glory vines around an elevation of 2,300 ft. Above this there are forests which are apparently made up of an arborescent species of Scalesia, and other trees. Orchids, and "sword ferns" were also noticed in the upper regions visited.

Tagus Cove.

Tagus Cove is located on the west side of the island about opposite the northeast corner of Narborough Island. It has been formed from and old tufa crater the southwest side of which has been removed leaving a small and well protected bay inside. The inner walls of the crater form steep bluffs which surround it on all sides except the one open to the sea. In some places these bluffs are 600 ft. high, but they are much lower than this towards the north end of the cove at which place a small ravine enters it.

There are also two other tufa craters in this vicinity. The smaller one of these is located just north of the cove and contains a miniature salt-water lake, while the larger is situated about a mile south near the coast. This third crater has probably formed a small bay some time in the past, as its walls are broken down on the side next to the sea, similar in this respect to the crater that forms Tagus Cove. The opening has been closed, however, by a flow of lava across it, and is now filled with salt water which comes in through the cracks in the lava from the sea a short distance away. There are four islets in this lake, one of which has a small crater on it. It is evident from the description, given by Darwin in his Voyage of the Beagle, that this is the salt water lake that he describes as being located near "Banks Cove". The sides of all these craters are much cut up by gullies which have been eroded in them. All three of the tufa craters just described, are separated from the base of the mountain by a plain, about one and a half miles wide, which is covered with deposits of volcanic cinder northeast of the cove. These cinder deposits extend along the base of the mountain northward and are continuous with the lava beds in the Banks Bay region. The cinder beds do not extend south of Tagus Cove, however, as the country around the base of the mountain in this direction, is covered with deposits of tufa, which extend out to the coast and form cliffs 40–50 ft. high.

The mountain lies northeast of the cove and is the second one of the three mountains that make up the northern part of the island. The mountain at Banks Bay is the one furtherest north, and the one at Cowley Bay furtherest south in the chain. The west side of the mountain, opposite the cove, is rather steep to an elevation of 2,500 ft. There are extensive deposits of tufa below this elevation, in which deep canyons have been eroded, and small gullies are common everywhere. There are two flows of comparatively recent lava, covering the tufa, and extending down the side of the mountain. They have evidently originated from small craters near an elevation of 2,500 ft. Deep fissures occur in these beds in places. The side of the mountain is covered with extensive deposits of partly disintegrated lava, above an elevaton of 2,500 ft., which is similar but much older than the lava which has formed the flows down the side below this elevation. The north side of the mountain seems to be entirely covered with lava.

The top of the mountain is 4,000 ft. above sea level so that this is probably the third highest mountain on the island, and the fourth highest in the archipelago, the mountains at Banks Bay, Iguana Cove, and the one on Narborough Island exceeding it in height. There is an immense crater at the top which is about four miles long and three broad as nearly as could be estimated. The inner walls of the crater are nearly perpendicular in places. The floor forms a broad flat plain, possibly 500 ft. below the rim, which is covered with volcanic ashes, and beds of basaltic lava, and cinders. There is a somewhat smaller crater inside the larger one.

The tufa hills in the vicinity of the cove are covered with a sparse growth of low bushes the most common species of which are: Acacia macracantha, Croton Scouleri var. Macraei, Euphorbia diffusa, Lipochaeta laricifolia, and Waltheria reticulata. There are also a few low trees of Bursera graveolens with rounded crowns, and a considerable amount of Opuntia insularis. There are many places where the ground is nearly bare of vegetation, and although we visited here in March at the end of the rainy season, the prospect was far from inviting. Several grasses occur in these open areas among which are: Aristida subspicata, Anthephora hemaphordita, Bouteloua pilosa, Cenchrus granularius, and other herbaceous plants.

With the exception of an occasional specimen of Cereus sclerocarpus the lava beds around the base of the mountain are bare of vegetation except in protected places where a few grasses and other small plants occasionally appear. On the flat area south of the lava beds, which is covered with tufaceous soil, the vegetation is thicker than it is on the tufa hills but is made up largely of the same species with the addition of a few others. Bushes and small trees are common here especially along the edges of the lava beds where they often grow to a larger size and occur in greater numbers than elsewhere. A few ferns are to be found in protected places in this region.

The tufa deposits above the base of the mountain are covered to a considerable elevation with forms which are practically the same as those on the plain below, except that the arrangement is somewhat different, there being many open areas which are covered with grasses and other herbaceous plants. The canyons here often have a heavy growth of Croton and Gossypium bushes which grow much taller than they do in the more exposed places outside the canyons. There is no very marked change in the character of the vegetation to an elevation of 2,500 ft., as far as the tufa deposits extend, except that the vegetation thickens up in places and such conspicuous forms as Pisonia floribunda, Tournefortia rufo-sericea, and Zanthoxylum Fagara are added. The two lava flows down the side of the mountain, which cover the tufa deposits, are bare of vegetation except for occasional bushes of Erigeron lancifolius, Euphorbia viminea, and Waltheria reticulata, while the only plant of tree-like proportions is Cereus sclerocarpus. In the deep crevices of this lava, however, there is a more abundant vegetation as trees and bushes of Bursera graveolens, Cordia lutea, and Zanthoxylum Fagara are to be found, as well as a few ferns, among which are Asplenium formosum and Notholaena sulphurea.

The side of the mountain above an elevation of 2,500 ft. is covered in most places with low bushes, the most common one of which is Lipochaeta laricifolia. This condition continues to within about 150 ft. below the rim of the crater, where there is a narrow zone covered with a dense, and almost an impenetrable growth of Pennisetum exalatum. The rim of the crater is covered with bushes of Cordia galapagensis, Croton Scouleri var. Macraei, Dodonaea viscosa var. spathulata, Lantana peduncularis, Maytenus obovata, Telanthera nudicaulis, and Scalesia microcephala. Opuntia myriacantha also occurs here but the specimens are smaller and not so profusely branched as they were lower down. There are a number of herbaceous plants and ferns among the other vegetation. The vegetation on the floor of the crater appeared to consist of occasional specimens of Cereus sclerocarpus and clumps of Dodonaea bushes.

It seemed impossible to divide this side of the mountain into botanical regions, as was done at the most of the other places visited. There is a great similarity in the vegetation all over this side, and the forms which occur at the top of the mountain are mostly of the same species which occur at or near the base. This rather peculiar condition is probably due to the fact that this side of the island gets very little of the moisture which is brought to the opposite side in the form of fog banks. Mr. R. H. Beck visited the south side of this mountain, in his search for tortoises, and reported it to be less sterile than the west side A small lateral crater, which occurs on the south side, appeared to be heavily covered with vegetation, when seen from the west side of the mountain.

Cowley Bay.

Cowley Bay is located on the east side of the island near its center. The shores around the bay and along the adjacent coast north of here, are composed of low cliffs of pumice and occasional pebble and sand beaches. A plain, covered with partly disintegrated pumice, extends inland from the shore to the base of the mountain, a distance of about half a mile. The east side of the mountain rises rather steeply to 2,000 ft., and is covered to this elevation with partly disintegrated pumice, similar to that on the plain below. Occasional ridges of lava protrude through the pumice in places so it is likely that these deposits are not very thick. The slope is more gradual above 2,000 ft. and continues so to within a few hundred feet of the rim of the crater. The sides of the crater's rim are quite steep. Apparently all of the mountain side above an elevation of 2,000 ft. is covered with basaltic lava which has become partly broken down into soil through which lava boulders project forming a rather rough surface in most places. The side of the mountain, a short distance south of the bay, is covered with deposits of recent lava to a considerable elevation. The west side of the mountain was not visited, but it was noticed while sailing past this side of the island, that the vegetation was quite heavy here so it is likely that this side of the mountain is covered with lava and not pumice.

There are but few halophytic plants in this vicinity, possibly due to the steep and unstable nature of the shores. A few bushes of Laguncularia racemosa were noticed, and a small grove of trees of Rhizophora Mangle were noticed a mile or two further south.

The region near the shore is almost bare of vegetation in many places, and with the exception of the more recent beds of lava on some of the other islands, it is the most sterile place botanically that we visited. What little vegetation there is here is very much scattered and consists largely of low Bursera and Croton bushes, and bushes of Cordia lutea, Discaria pauciflora, Dodonaea viscosa, Lipochaeta laricifolia, Maytenus obovata and Scalesia gummifera, all of which are rather stunted except when they occur in protected places. We visited this place during the dry season but it is not likely that conditions would be much more inviting during the rainy season, because very few remains of annual plants were found.

The lower slopes of the mountain are more heavily covered with vegetation than is the plain just mentioned, but even here there are often areas of a considerable size which have scarcely any vegetation on them. The species which occur on the plain also occur on the side of the mountain in greater number, and many of them that were stunted on the lower part, reach their normal size around an elevation of 1,000 ft. The increase in the humidity of the atmosphere is shown at this elevation, and above, by the large amount of Usnea longissima, and other lichens, which cover the vegetation to such an extent as to give it a grayish appearance. A number of mesophytic plants were first seen around 1,300 ft. elevation, the most noticeable of which were: Pisonia floribnda, Psidium galapageium, and Scalesia microcephala, the last of which forms a zone on this side of the mountain to an elevation of 1,650 ft. There are also a great many Bursera trees at an elevation of 1,200 ft. and above. Below this they were few in number. Ferns begin to appear at a slightly higher elevation.

There is an abrupt change in the appearance of the vegetation at an elevation of 2,000 ft. The character of the soil also changes here from pumice to disintegrated lava mixed with vegetable mold, so that the change in the vegetation is due more to an increase in the number and size of plants than to a sudden change of forms. There are heavy forests here made up of trees of Bursera graveolens, Pisonia floribunda, Psidium galapageium, and Zanthoxylum Fagara as well as many species of bushes the most of which were found at a lower elevation although usually smaller in size. The trees are often covered with vines of Cissampelos Pareira, and fruticose lichens continue to be abundant. Ferns are also abundant, the common species being Adianaum concinnum, Doryopteris pedata, Polypodium pectinatum, and Trachypteris pinnata. Small specimens of Opuntia myriacantha were seen at this elevation and they continue to within a few hundred feet of the top of the mountain according to Mr. R. H. Beck, who visited this region.

The sides of this mountain were not explored botanically above an elevation of 2,100 ft. From the top of a tree at this elevation, the whole of the country beyond could be seen. The character of the vegetation did not seem to change until the steep slope, below the rim of the crater is reached. Just below the rim, in several places, there were light green areas which, according to

Mr. Beck, are covered with a tangled growth of bushes and morning glory vines.

The conditions on this side of the mountain are such that it is very difficult to determine the extent in elevation of the botanical regions, the nature of the soil being such as to cause xerophytic plants to predominate higher up than would probably be the case if the lower part of the mountain was covered with a more suitable soil. The transition region evidently begins around an elevation of 1,200 ft. and it probably extends up to within about 500 ft. in elevation, from the top of the mountain.

Iguana Cove.

Iguana Cove is a slight identation in the shoreline on the southwest side of the island. It is somewhat protected from the direct action of the swell, but owing to its small size, it does not afford an anchorage inside. The anchorage is just outside the cove, but owing to the fact that there are jagged rocks projecting from the water a short distance from it, on which the swell breaks heavily, it is dangerous to anchor here except in calm weather. The shores are precipitous in this vicinity, being made up of bluffs, which in places rise to a height of 200 ft. These tall bluffs do not come down to the shore, however, except in one place; in other places there is a low flat plain intervening between them and the shore. In the vicinity of Christopher Point, just north of the cove, the shores are made up of low lava cliffs, and the country back of them is covered with rather recent lava on which there is apparently very little vegetation. In the immediate vicinity of Christopher Point there are many small craters and blowholes which rise fifty or more feet in height, and which give the surrounding country a weird and grotesque appearance. South of the cove the shores are made up of low cliffs with occasional shelving beaches of gravel and sand.

The mountain northeast of Iguana Cove is a broad flat-topped crater which probably rises to a height of 5,000 or more feet. As the weather was very bad when this place was visited, no attempt was made to reach the top of the mountain. The sides are very steep here, and are covered with a considerable amount of soil, composed of disintegrated lava and vegetable mold, which supports a heavy growth of vegetation. The north side of the mountain is not so steep and is covered with beds of barren lava in which there are occasional islands of older lava which are covered with xerophytic vegetation.

The botanical conditions in the vicinity of Iguana Cove are rather unique, as it is the only place on the islands where an extensive mesophytic vegetation occurs near sea level. It is very likely that the steep slope has something to do with this, as no such conditions are found a short distance south of the cove where the slope is more gradual.

The halophytic flora is of no consequence here due probably to the steep shores. There are mangrove swamps, however, along the north shore of this part of the island between Christopher Point and Elizabeth Bay, and on the south shore between Essex Point and Cape Rose.

The flat area at the base of the cliffs, just south of the cove, is covered with a heavy growth of bushes consisting for the most part of: Cordia Hookeriana, Cryptocarpus pyriformis, Tournefortia rufo-sericea, and Zanthoxylum Fagara. This condition continues for some distance down the coast was found out by some members of the party who attempted to come overland. The sides of the cliffs just back of the cove, are pendicular so that it is difficult to scale them except, in a few places where they are somewhat shelving. In such places there are a few trees and bushes, and a considerable number of herbaceous plants and ferns. Above the top of the cliff there is a heavy growth of vegetation consisting of trees of Bursera graveolens, Pisonia floribunda, Scalesia Cordata, and Zanthoxylum Fagara, the last of which is usually heavily covered with Phoradendron Henslovii. There are usually thick tangled masses of bushes which are heavily overgrown with such vines as Cissampelos Pareira and Ipomoea Bona-nox. Many ferns, both epiphytic and terrestrial, occur here.

Owing to the rainy weather, while we were at this place, no plants were collected above 500 ft. The conditions at this elevation were about the same as those near the tops of the cliffs above the cove, except that there were occasional open places in the vegetation, which were covered with ferns and grasses. These areas get larger a little higher up. Mr. R. E. Snodgrass climbed about half way up the side of this mountain when he visited these islands several years ago. He has told me that apparently the rest of the way up, the vegetation is made up of dense fern brakes with irregular rows of shrubs running through them. It was noticed from the shore that the vegetation had a streaked appearance about half way up the side of the mountain. It appeared to be made up of alternating light and dark bands, and suggested that there might be flows of different kinds of lava in this region, each of which presented conditions peculiarly adapted for the growth of certain species of plants.

The country around the top of the mountain was examined through a field glass on a clear day later in the season as we were sailing past this part of the island. The vegetation appeared to be smaller than lower down and it was rather grayish in color instead of dark green. It is very likely that the upper part of this mountain receives less moisture than does the middle part. The upper part of this mountain could be plainly seen from the top of the mountain at Villamil when we visited there. The lower part of the mountain, however, was entirely hidden by the fog at this time. It was also noticed that much of the soil on top of the Villamil mountain was dry while lower down it was wet. The fog banks apparently hang low when they strike the islands.

Turtle Cove.

Turtle Cove is on the south side of the island about six miles west of Villamil. The coast in this vicinity is low and rocky with occasional sand beaches, while back of the coast the country is low and covered with beds of basaltic lava for a considerable distance inland. There are springs of comparatively fresh water and pools of strongly brackish water in the vicinity of the shore and farther inland.

There were large trees of Avicennia officinalis on the sand beach where we landed, back of which there is a swampy area covered with a dense growth of Conocarpus erectus and trees of Rhizophora Mangle. Rhizophora occurs for some distance inland, surrounding the pools of brackish water. It also occurs in isolated patches on the open coast, but owing to the fact that the surf breaks heavily here at times, none of these are extensive. Thickets of Laguncularia racemosa are also to be found in places in the vicinity of the shore and there are quite a number of small trees of Hibiscus tiliaceus, and bushes of Tournefortia rufo-sericea.

The vegetation on the inland country consists of plants usualy found in the dry regions except that there is an unusually large number of trees of Hippomane Mancinella. Other common trees are those of Bursera graveolens and Opuntia myriacantha. The country adjacent to the coast, just east of this place, is covered with dense thickets of Cryptocarpus pyriformis apparently to the exclusion of all other vegetation of any size. West of here, in the vicinity of Cape Rose, there are extensive deposits of volcanic cinders on which the vegetation is very open, probably due to the fact that the lava has disintegrated but little. What few plants that do occur here are for the most part, the ones that are commonly found in the dry regions of these islands.

All of the country which lies between the mountain at Iguana Cove, and the one northwest of Villamil is low, probably in no place exceeding an elevation of 200 ft.

Vilamil.

Villamil is on the south side of the island about seven miles northwest of Brattle Island. A settlement of about one hundred and fifty people was established here some years ago, by Mr. Antonio Gil of Guayaquil, Ecuador. A considerable industry in hides, molasses, and sulphur is carried on, the products of which are sent to Guayaquil by means of a small vessel which makes periodic trips to the mainland. A part of the settlement is located near the shore, but the most of it is about twelve miles inland, at an elevation of 1,300 ft., where there are plantations of sugarcane, bananas, and other tropical fruits and vegetables.

Villamil Bay is surrounded by low beds of basaltic lava, but west of the settlement on the open coast, there are extensive sand beaches. These are continuous with a broad sand-flat just back of them, which extends back for about half a mile. The country for several miles inland is flat and is covered with beds of basaltic lava and volcanic cinders which usually lie almost horizontally. There are numerous crevices in the lava, in some of which there are pools and springs of nearly fresh water. Owing to the low elevation of this part of the island, these springs usually occur only a few feet below the level of the ground. There is a considerable amount of precipitation on the upper part of this island, in the form of fog and rain. There is not sufficient soil to retain this water, however, so it percolates through the lava and comes out again near sea level. On this account the water is usually slightly brackish even at a considerable distance inland.

The flat country extends inland for about four miles, to the base of the mountain. Above this the slope is very gradual to an elevation of 500 ft. So far as could be observed, this side of the mountain is covered with volcanic cinder, which has become slightly disintegrated and mixed with vegetable mold, forming a scant soil. The slope is less gradual above 500 ft. and continues so to an elevation of 2,400 ft. This part of the mountain side is rather rolling and slightly terraced in places. There is sufficient soil over the upper part of the mountain to completely cover the lava except on ridges and other exposed places. The slope of the mountain side is quite abrupt above 2,400 ft. to the rim of the crater, which has an elevation of 3,150 ft.

As near as could be estimated the crater is about seven miles long and four miles broad, the greatest diameter being approximately east and west. The floor of the crater is flat at its eastern end and is filled with numerous crevices through some of which vapors issue periodically. There is a prominent ridge near the center of the crater which rises gradually in height until at its west end it is nearly as high as the rim. A small active sulphur volcano is situated on the south side of this ridge, and still another larger one at its west end around both of which there are deposits of sulphur. It is from this place that the inhabitants obtain the sulphur which they export to Ecuador.

Small swamps of Rhizophora Mangle occur in places around Villamil Bay, and trees of Avicennia officinalis, and bushes and trees of Laguncularia racemosa are to be found in several places near the coast. Quite a grove of these occurs near the settlement. Along the sand beaches west of the bay, there are many small halophytic and semihalophytic plants such as: Cryptocarpus pyriformis, Heliotropium curassavicum, Ipomoea Pes-caprae, and Scaevola Plumieri. The sand flat, back of the beach, is covered with a dense growth of Sporobolus virginicus in which there are small groves of Hippomane Mancinella trees, and bushes of Cryptocarpus pyriformis. In places around the edges of the sand-flat there are thickets of Conocarpus erectus, some of which form trees twenty-five or more feet high.

There is a low area of limited extent about a mile west of Villamil in which the soil is kept moist by the water which comes down through the lava from the interior. There are quite a number of mesophytic plants here. Vines of Argyreia tiliaefolia and Cissampelos Pareira cover the rocks in places and there is a small grove of trees of Anona glabra and ferns. The inhabitants have planted a garden in this place which has been quite successful as bananas and other tropical plants grow there. The change from xerophytic to the mesophytic type of vegetation is very abrupt here, as such pronounced xerophytes as Lantana peduncularis, Opuntia myriacantha, and Prosopis dulcis are found growing only a few feet away from the mesophytic plants enumerated above. There are several low marshy areas, filled with brackish water, in the vicinity of the settlement, in which there is a heavy growth of Eleocharis mutata. The stems of this plant are used by the inhabitants for making mats. The higher land between these marshes is covered with low and rather open forests consisting of trees of Acacia macracantha, Bursera graveolens, Hippomane Mancinella, and Opuntia myriacantha, among which there are bushes of Chiococca alba, Clerodendron molle, Cordia lutea, Gossypium barbadense, and bushes and small trees of Zanthoxylum Fagara on which Phoradendron Henslovii is often found. In many of the lava crevices, which are deep enough to reach the ground water, there are large bunches of Cyperus ligularis.

On the broad plain some distance inland, there are beds of basaltic lava and volcanic cinder of a considerable width. The basaltic lava is often heavily covered with vegetation and in one place an entire flow is covered with a forest of Opuntia myriacantha trees, underneath which there are low dense thickets of Euphorbia viminea and occasional bushes of Acacia macracantha. Cyperus Mutisii was found growing abundantly in the smaller crevices of the lava in this area. The vegetation on the cinder deposits, however, is very open and consists mostly of occasional bushes, or small clumps of bushes, of Clerodendron molle, Erigeron tenuifolius, Lippia rosmarinifolia, and Scalesia gummifera on many of which there was a dense growth of vines of Cardiospermum galapageium, and Passiflora subrosa. Between the bushes the ground is often bare for some distance.

In one place, several miles inland, there is a low area which had the general appearance of having been filled with water at some time. There is much more soil here than in any place in this vicinity. There are pools here which seem to contain water the most of the time, around which Cyperus laevigatus and Sporobolus virginicus grow. Groves of Hippomane Mancinella grow in this area, in the shade of which there are bushes of Caesalpina Bonducella, Cryptocarpus pyriformis, Discaria pauciflora, Scalesia gummifera, and Solanum verbascifolium. In the more open places in this area there were large bunches of Panicum fasciculatum and other herbaceous plants. On barren lava beds and on exposed ridges in this vicinity, Cereus sclerocarpus was the only plant that grew to any considerable size.

A change takes place in the vegetation between an elevation of 100 and 200 ft. where many of the plants common below disappear, the most common of which are: Acacia macracantha, Castela galapageia, Cereus sclerocarpus, Discaria pauciflora, Euphorbia viminea, and Waltheria reticulata, while such prominent woodland plants as Pisonia floribunda, Psidium galapageium, and Scalesia cordata begin to appear along with ferns and other plants, which are found abundantly higher up. There is a general thickening above an elevation of 200 ft. and fruticose lichens are very abundant on trees and bushes.

Sapindus saponaria was first seen around 250 ft. elevation. There are only occasional trees of this species at this elevation, the dense Saponaria forests not beginning for another hundred feet or so in elevation. Scalesia cordata also increases in abundance so that the forest trees throughout the moist region consist mostly of these two species. There is a heavy growth of bushes in these forests, increasing with the elevation, which consist largely of the following species. Clerodendron molle, Croton Scouleri var. grandifolius, Erigeron tenuifolius, Psychotria rufipes, Tournefortia psilostachya, T. pubescens, and T. rufo-sericea. There are many ferns both terrestrial and epiphytic, the common epiphytic species being: Polypodium lanceolatum, and P. lepidopteris, while on the higher branches of many of the trees there are large bunches of Lycopodium dichotomum. Other common epiphytes in this region are Ionopsis utricularioides, Peperomia galapagensis, P. Stewarti, and Tillandsia insularis. There are a large number of trees of Hippomane Mancinella in the forests at an elevation of 600 ft. but none were found below this, except near sea level.

A considerable amount of the forest has been cleared away between 600 and 1,300 ft. elevation. Much of this area has since been neglected and has grown up in bushes of Tournefortia rufosericea which are heavily covered in places with vines of Argyreia tiliaefolia, and Ipomoea Bona-nox. There is also usually a heavy growth of grass in between the bushes, and brakes of Pteris aquilina var. esculenta are not uncommon. The forest bordering the cleared area seems to be made up mostly of the same forms found around an elevation of 600 ft., where the cleared area begins, but the lower part of it was not carefully explored. The vegetation becomes much thinner in the uncleared areas above 1,200 ft. elevation and with the exception of an occasional tree of Sapindus saponaria, there are no trees of large size. The country is covered with open woodland made up largely of small trees and bushes of Croton Scouleri var. grandifolius, Scalesia cordata, Solanum verbascifolium, Tournefortia rufo-sericea, Urera alceaefolia, Zanthoxylum Fagara, many epiphytic plants and ferns. There are many park-like areas in the woodland which are covered with grasses. The trees become smaller and more scattered to an elevation of 1,500 ft., where they end rather abruptly.

The side of the mountain above 1,500 ft. elevation is somewhat rolling and is covered with grassland on which large numbers of cattle graze, which are slaughtered by the inhabitants of the island for their hides. Paspalum conjugatum is the principal species of grass found in this region. This condition continues to an elevation of 2,400 ft, above which there is a decrease in the amount of grass and a large increase in the fern flora. Small tree ferns, Hemitelia multiflora, and other large species of ferns are common from here to the top of the mountain.

There is a great difference in the vegetation of the outer and inner sides of the southern rim of the crater, where the most of the collecting around the top of the mountain was done. The outside of the rim at this place is mostly covered with small vegetation consisting of ferns, club-mosses, and small herbaceous forms, all of which lie close to the ground, and it is only in places which are protected from the wind that plants of any size are to be found. Just over the rim of the crater, however, there is a considerable growth of bushes of Duranta repens, Erigeron lancifolius var. glabriusculus, Solanum verbascifolium, Zanthoxylum Fagara, and other bushes. Hemitelia multiflora also occurs here in large numbers and such other ferns as Asplenium Serra, Dryopteris parasitica, Elaphoglossum muscosum, Polypodium aureum, and Polystichum aculeatum abound.

A gradual change from a mesophytic to a xerophytic vegetation can be readily noticed as one travels around the southern rim of the crater towards the northwest side, but as our time was limited when this region was visited, no collections were made.

The floor of the crater is 400 ft. below the rim, and was examined near the west end, in the vicinity of one of the active volcanoes. Here were found patches of Sporobolus indicus covering considerable areas in places while other areas were covered with Gnaphalium luteo-album, the gray color of which caused them to stand out prominently when the floor was viewed from the rim. There were also occasional specimens of an arborescent species of Cereus, and low stunted specimens of Opuntia myriacantha. An occasional tree of Zanthoxylum Fagara was seen, usually close to the crater's wall. There is a considerable growth of stunted bushes in places consisting mostly of: Clerodendron molle, Dodonaea viscosa, Euphorbia equisetiformis, and Lipochaeta laricifolia. There were brakes of Pteris aquilina var. esculenta in one place, but outside of this, ferns are few at this end of the crater.

The northwest side of the mountain seems to be covered with grassland, which is much drier than are the south and southeast sides. At least it appeared to be as far down on this side as we could see from the top of the mountain. The soil on the rim of the crater was also much dryer on this side than it was on the southeast side.

The dry region is confined largely to the broad flat plain at the base of the mountain at this place. As near as could be determined it does not extend above an elevation of 150 ft. Above this many of the mesophytic forms appear, and there is a large amount of fruticose lichen on the vegetation, indicating a greater humidity. The transition region forms a narrow belt along the base of the mountain, the upper limits of which reach to an elevation of about 350 ft. The lower part of the moist region is covered with dense forests of Saponaria, and Scalesia trees, while on the upper part the vegetation consists mostly of bushes, and small trees with open spaces between them at intervals. Near the upper limit of this region, around an elevation of 1,500 ft., there are only low bushes. The grassy region extends from 1,500 ft. nearly to the top of the mountain.

Barrington Island.

Barrington is situated ten miles southeast of Indefatigable, and twenty-six miles west of Chatham Island. It is one of the smaller islands of the group, and it is of low altitude the most of it not reaching an elevation of over 350 ft. There is a hill near the northwest side, however, which attains an elevation of 650 ft. This hill ends abruptly at the top of a tall bluff which drops almost straight downward into the sea. The shores of the island are made up of low lava cliffs for the most part, but there is a small bay on the northeast side, which is surrounded by sand-beaches. This bay is sheltered by a small islet and a reef, Although this bay can not be entered by vessels, it nevertheless affords an excellent landing place for boats.

Topographically the island is made up mostly of alternating ridges and valleys which have a general trend towards the southeast. The ridges, in a general way, are 100 ft. higher than the valleys, and are covered with tumbled masses of lava. The valleys, on the other hand, usually have a considerable amount of soil in them, the most of which has probably been formed on the sides of the ridges and washed down. The soil varies from a light brown to an ochre color, and is very light in texture. The lava all seems to be basaltic in character and is evidently quite old as it has become stained to a redish-brown color.

The only plants found on the sand-beaches surrounding the bay, were bushes of Cryptocarpus pyriformis, and mat-like growths of Sesuvium Edmonstonei both of which are not exclusively halophytic in their habits. The shores on other parts of the island are too steep to support halophytes. A short distance inland from the beach there are low thickets of Discaria, and Maytenus bushes.

Owing to a low altitude, all of the vegetation in the interior of the island is very xerophytic in character, and about the only noticeable change that takes place in the vegetation towards the higher parts is the greater abundance of fruticose lichens. The most noticeable plants are the large trees of Opuntia myriacantha which grow in great numbers over the most of the island. Small trees of Bursera graveolens also occur, much infested with lichens. There was a fair growth of bushes in most places, consisting for the most part of such species as: Cordia lutea, Corton Scouleri, Gossypium barbadense, Lantana peduncularis, Telanthera echinocephala and Scalesia Helleri, the last one of which was the only conspicuous green plant to be found on the interior of the island at the times we visited it. In the valleys between the ridges there were small areas which are covered with a growth of Euphorbia viminea forma barringtonensis. In other places in these valleys where the soil is loose there is an abundance of Coldenia fusca.

This island was visited during the months of July and October, in consequence of which the annual vegetation, which comes on during the rainy season, was missed entirely. Very few remains of such plants were found on either of our visits as goats have been introduced upon this island during the last few years which eat up all of the edible vegetation as fast as it grows. Even the trunks of the large Opuntia trees do not escape their ravages.

Bindloe Island.

This island is the largest of the group of three which lie some distance north of the main part of the archipelago. It is eight miles long, six and one-half miles broad, and its highest part attains an elevation of 800 ft. according to the chart issued by the Hydrographic Office. When seen from a distance the island appears to be made up of numerous small peaks which vary in elevation. The greater part of the island is covered with beds of recent lava which consist mostly of volcanic cinder. The whole of the north side, along which we sailed, is covered with such deposits, on which there are occasional exposures of older lava which support a considerable amount of vegetation.

We anchored on the northeast side of the island near where a broad strip of country, covered with deposits of tufa, extends down to the shore. This area is covered with vegetation, apparently the largest continuous body of such on the island.

A few small green patches, evidently halophytic plants of of some kind, were noticed along the north shore of the island as we were sailing past it. With this exception, no halophytes were seen, as the shores are too steep in most places to support them.

The vegetation is arranged in irregular clumps in the vicinity of the shore with broad open lanes between them. The vegetation here is made up mostly of low bushes of Euphorbia amplexicaule, E. articulata, Castela galapageia, and low thickets of Opuntia. This open arrangement disappears inland and the country is heavily covered with xerophytic vegetation. The only trees found here are those of Bursera graveolens which grow quite large considering the very dry conditions which prevail. They are sometimes covered with vines of Ipomoea Habeliana, the only place on the islands where this species assumes the climbing habit in such a pronounced way.

The edges of recent flows of lava are often bordered with bushes of Cordia lutea, and Waltheria reticulata forma intermedia, both of which occur in other places but less abundantly.

No collecting was done on the upper part of the island, but according to Mr. Beck, who visited this part, the country is covered with beds of recent lava which have but little vegetation on them. There are a few moist places, in the vicinity of steam-vents, in this region, around which such ferns as Ceropteris tartarea, Nephrolepis biserrata, and Polypodium squamatum grow to some extent. The whole of the island may be included in the dry region.

Brattle Island.

Brattle is a small island, that is situated about four miles off the south side of Albemarle Island near its eastern end. It is a semilunar in general outline and is the remains of an old tufa crater the south and west sides of which have been eroded away, except in two places, where there are small islets. The top of the island is 275 ft. above sea level, and the sides are very steep and much cut up with gullies and ravines. Owing to the steep nature of the shores landing is difficult, and can only be done with safety on the north side, when the water is comparatively still.

The greater part of the surface of the island is bare of vegetation, a condition that is probably due to the steep sides and the loose soil, which is composed of volcanic ashes and small bits of lava loosely cemented together.

The most common plant on the island is a low bush which is covered with thick, succulent leaves, and which forms thickets around the top in various places. This plant was neither in flower or fruit at the time the island was visited so it could not be identified with certainty. Bushes of Croton Scouleri occur along the sides to some extent, but they are stunted and the leaves are smaller here than is usually the case with this species. Three species of herbaceous plants: Coldenia fusca, Ipomoea Kinbergi, and Tribulus cistoides were found at the top, as well as the remains of several grasses. Two lichens, Ramalina complanata and Rocella peruensis are also found.

Charles Island.

With the exception of Hood, this is the most southerly island in the group. It is located about thirty-seven miles south of Indefatigable Island. The island is ten miles long and eight miles broad. It reaches an elevation of 1,780 ft. at its highest point. Geologically it is probably one of the oldest islands in the group, and volcanic activity upon it has evidently long since ceased. There are no deposits of even comparatively recent volcanic material upon it.

In approaching the island from the south, one is impressed with the number of large craters on it. Fourteen of these were counted, seven of which were larger than the rest. The tops of the most of the craters are evenly rounded, and it was found out later that the southeast sides of many of them were broken down. The slope is quite gradual from the shore to the central region, on all sides but the east. This side was not visited, but in sailing along the shore, the slope appeared to be rather steep, and was covered with xerophytic vegetation among which were a large number of Cereus.

There is a fair amount of soil in most places, composed of volcanic ashes and bits of lava. There are exposures of lava, however, on which there is but little soil, but they are less common than on other islands visited. The central part of the island is covered with a plateau, several miles square, which has an average elevation of 1,000 ft. Several large tufa craters are located on the plateau, which usually rise 500–800 ft. above it. Springs occur around the base of one of these, and a considerable amount of water is afforded by one of them. Such domesticated animals as: Cattle, hogs, goats, cats, and dogs have been introduced upon the island. The inhabitants from Chatham island often come here to dry beef for the use of the laborers on that island.

Black Beach Road.

Black Beach Road is located on the west side of the island and was the port for the settlement which was located on this island many years ago. A good trail leads inland from here so the central region is more accessible than on the most of the other uninhabited islands.

The shores are low and rocky in the vicinity of Black Beach Road, against which the surf breaks heavily at times. On this account there are no halophytes to speak of except a small bunch of rather stunted mangroves a short distance south of the landing place.

The region north and east of this place is covered with a fair amount of ashy soil through which the lava seldom appears. South of here, however, there are exposures of lava, covered for the most part with Croton bushes. Just back of the landing place there is a flat area covered with bushes and small trees of Maytenus obovata and Prosopis dulcis. Another small area occurs a few hndred yards north of the landing place near the coast, which is covered with tumbled masses of lava among which Cereus galapagensis, Lecocarpus pinnatifidus, Mentzelia aspera, and Scalesia decurrens grow.

The larger vegetation to an elevation of 450 ft. consists of trees of Bursera graveolens, and Opuntia galapageia. In the vicinity of the shore there are also trees of Cereus galapagensis. The vegetation is all rather open but there are a considerable number of bushes of Cordia lutea, Croton Scouleri var. Macraei, Lantana peduncularis, Maytenus obovata, Gossypium barbadense, and Vallesia pubescens. Acacia macracantha and Prosopis dulcis also occur in this region to some extent but they assume the size of trees around 450 ft. There are remains of an old settlement at this elevation which is marked by a grove of Geoffroea striata and other trees, as well as by a few other domesticated plants of smaller size. There was evidently a spring of water here at some former time but it was dry at the times this place was visited.

A decided change takes place in the vegetation above an elevation of 450 ft. For possibly the first 200 ft. there are large bunches of bushes of Clerodendron molle, in between which are grasses and smaller plants. This is succeeded above by more open country on which there are occasional Bursera trees and bushes, the most common of which are, Capraria biflora, and Lipochaeta laricifolia. Perennial grasses grow between the bushes, to which a considerable number of annual forms are added during the rainy season.

The plateau region, around an elevation of 1,000 ft., is covered with stretches of rather open woodland, and meadow. The woodland usually occurs where the lava is exposed or reaches nearly to the surface of the ground. In these areas trees of Scalesia pedunculata are common but they do not grow to as large a size as they do on some of the other islands where this species occurs. Other trees in the woodland besides those that have evidently been introduced are: Pisonia floribunda, and Zanthoxylum Fagara, the last one of which is often heavily covered with Phoradendron Henslovii, as often happens when this tree grows where there is a considerable amount of moisture. Common bushes in the woodland are: Capraria biflora, Croton Scouleri varieties brevifolius and grandifolius, Erigeron tenuifolius, Psychotria rufipes, Tournefortia psilostachya, and T. rufo-sericea. The soil is ashy in the meadows, with small fragments of lava scattered through it. Grasses and herbaceous plants occur here, the common species being: Aristida subspicata, Eleusine indica, Eragrostis ciliaris, Acalypha parvula, Lippia canescens, Malvastrum americanum, Plumbago scandens, and Stachytarpheta dichotoma. Many evidences of former habitation appear in the flora throughout the plateau region as such introduced species as Ambrosia artemisiaefolia, Bixa Orellana, Datura Tatula, Inga edulis, Spondians purpurea, orange, lemon, and lime trees grow there in greater or less abundance. The lime trees are the most common of these, and there are areas of considerable size which are covered with them. They seem to spread mostly in the open meadows as there are but few of them in the woodland. Probably in time they will cover all of the open country in the plateau region. The limes and lemons are of good quality and many tons of them rot on the ground each year.

The main crater rises to a height of 1,780 ft., and is covered on the outside with a heavy growth of bushes of Lipochaeta laricifolia, to within about 400 ft. of the top. This condition is found on all sides but the south and southeast. The bushes gradually disappear towards the south side of the crater and their place is taken by a heavy growth of Stachytarpheta dichotoma. Above an elevation of 1,450 ft. the outside of the crater is covered with low bushes of Capraria biflora, occasional bushes of Tournefortia rufo-sericea, grasses and other herbaceous plants the last of which are dried up during the greater part of the year, giving this part of the mountain a very barren appearance the most of the time. One will be greatly surprised if he should climb the west side of this crater during the dry season. On this side Opuntia galapageia grows to an elevation of 1,300 ft. The other plants which occur here and above are of a xerophytic type and continue so to the top of the mountain. Upon going over the rim, into the interior of the crater this condition changes and the plants which occur. there are decidedly mesophytic Small trees of Acnistus ellipticus grow there which are covered with such epiphytes as: Lycopodium taxifolium, Polypodium lanceolatum, Peperomia ramulosa and leafy Hepatics. Ferns and herbaceous plants are also common in this vicinity. The sudden change in the character of the vegetation within such a short distance is due to the fact that the moist winds strike the inner side of the crater and keep the vegetation damp the most of the time, while they pass directly over the top so that the moisture seldom descends far upon the leeward side. The inside of the crater is covered, a short distance below the top, with bushes and occasional small trees of Zanthoxylum Fagara all of which bear numerous epiphytic plants. Ferns are common in the crevices of the lava. The floor of this crater is covered with trees of Scalesia pedunculata and bushes.

There are several other craters in the upper regions which do not reach as great an elevation as the one described above. For the most part, they are covered with a heavy growth of lime trees and bushes on their leeward sides while the windward sides are covered with low bushes and herbaceous plants above an elevation of 1,300 ft.

It seems impossible to make out distinct botanical regions here as can be done on some of the other larger and higher islands of the group. For some reason or other, this island apparently does not receive as much moisture as do the other islands of similar elevation. In consequence of this the upper part, including the plateau, is covered with a mixture of both xerophytic and mesophytic forms, the last of which, however, are more abundant than they commonly are in the transition regions on the other islands. There are a few places in which there is a suggestion of a moist region but these are very limited in extent, dependent upon some very local condition or conditions. The country below an elevation of 1,000 ft. can be divided into open woodland below and bushy country above, the line of separation between the two being at about 450 ft. elevation.

Cormorant Bay.

Cormorant Bay is an open sheet of water situated on the north side of the island a short distance east of Post Office Bay. There are several sand beaches along the shore here on which Batis maritima, Lycium sp., Scaevola Plumieri, Sesuvium Edmonstonei, and S. portulacastrum grow quite commonly, while at the west end of the bay there is a small swamp of Rhizophora Mangle. A short distance back of the bay there is a small lake, the water in which has become saturated with salt and a layer has crystalized out which is thick enough in places to support one's weight. A number of trees of Avicennia officinalis grow in the water on the edge of this lake. There is a heavy growth of pneumatophores and mats of Sesuvium Edmonstonei in the water beneath these trees. There are some exposures of lava in this vicinity on which there is little vegetation besides Cacti and a few bushes. Around the base of a small crater, near the east end of the bay, there are bushes of Acacia macracantha, Cordia lutea, Cryptocarpus pyriformis, and Scalesia villosa. There is another small crater, about a half mile inland, the sides of which seemed to be covered with Bursera trees and Croton bushes.

Post-Office Bay.

Post Office Bay lies about two miles west of Cormorant Bay, just mentioned. This bay derives its name from the fact that the British Warship Leander placed a barrel on a post there many years ago, in which vessels which visited this place could deposit letters. The next vessel that called was supposed to take them out and carry them to their next port of call. Several of the members of the party, including the writer, mailed letters here which reached their destination some eighteen months later.

The interior region, on the north side of the island, was visited from this place, and was found to be much rougher than was the region near Black Beach Road on the west side of the island. There are several small craters on this part, the highest one visited having an elevation of 700 ft. There are broad valleys between the craters in some of which there were low rocky areas which might have contained water at some time as there were rounded boulders in them which had the appearance of having been water-worn.

The coast, along the south side of the bay, is rocky with occasional sand beaches on which there are a few patches of Rhizophora Mangle, and trees of Avicennia officinalis. This, by the way, is the only place on the islands where Avicennia grows so close to the open sea that its roots were covered with water at high tide. There are also dense thickets of Laguncularia racemosa in one or two places near the shore. In the sandy soil near the shore there are thickets of Cryptocarpus pyriformis, and Discaria pauciflora.

The low areas in between the craters in the interior region, are usually covered with such a thick growth of bushes of Prosopis dulcis as to render traveling difficult. In such places Castela galapageia, Maytenus obovata, Parkinsonia aculeatat, Vallesia pubescens, and Waltheria reticulata forma intermedia are also found. In addition to these a considerable number of herbaceous plants occur among which are: Abutilon crispum, Aristida suspicata, Bidens refracta, Cyperus Mutisii, and Tetramerium hispidum. The sides of the craters are rather steep and support a more open vegetation than the valleys surrounding them. Plants which commonly occur on the sides of these craters are: Acacia macracantha, Chiococca alba, Scalesia affinis, and S. villosa. The interior of some of these craters were filled with a heavy growth of Parikinsonia aculeata. No ferns or other distinctly mesophytic plants were found on this side of the island, to an elevation of 700 ft., as high as it was explored.

Chatham Island.

Chatham is the most eastern island of the group. It is the fifth in size, being exceeded in this respect by Albemarle, Indefatigable, Narborough, and James Islands. It is twenty-three miles long and about ten miles broad, the greatest diameter of which extends northeast and southwest. Geologically the island is probably very old as there are few evidences of recent volcanic activity, except in the vicinity of Sappho Cove, on the west side of the island.

The southern part of the island is most visited as there is a settlement located several miles inland, from which has a good wagon road leads down to Wreck Bay. This part of the island is rather flat for some distance inland, and is covered with a considerable amount of soil through which lava boulders project. There are several low lava hills on this part. The northeastern and eastern parts of the island were not visited, but a general survey of these was made from the vessel, and from higher parts in the interior of the island. The region around Terrapin Road, and for a considerable distance south, is covered by a broad plain which slopes gradually upward towards the southwest. There are several steep hills on this portion of the island some of which probably rise to a height of 500 ft. The color and general appearance of these hills indicated that they were composed of tufa. This part of the island is covered with forests, apparently made up of the forms usually found on the dryer parts of these islands.

There is a strip of country south of the wooded arear which is covered with beds of basaltic lava on which there is apparently little or no vegetation. This is followed on the southwest by still another area covered with vegetation, which extends down to within possibly three miles of Finger Point. East and south of Finger Point the country is again covered with lava, a portion of which is evidently volcanic cinders. There are many small craters on the lava in this vicinity, fifty of which were counted while sailing past this part of the island.

The country around the northeastern end of the island, and for some distance southwest along the east coast, is apparently very similar to that around Terrapin Road. We did not get very close to this part of the island so no very exact observations could be made of its close features. The country around Fresh Water Bay, on the south side, is quite steep and is heavily covered with dark green vegetation well down towards the shore. A stream of water is said to enter the sea at Fresh Water Bay, but as there is no good anchorage here it was not visited.

The interior part of the southern half of the island is a broad plateau which varies in elevation from 900–1,600 ft. The plateau is rolling and there are numeros small ravines which have streams of water in them during a part of the year. Small marshes are formed in some of the lower places in this region during the rainy season, but they quickly dry up soon after the dry season sets in again. The main central mountain rises to a height of 2,100 ft. and is composed of bits of volcanic cinders and other fragmentary material all of which is very much decomposed. There is no indication of a crater here, the mountain apparently being a huge pile of volcanic debris. A small crater lake is located on this plateau but was not visited for botanical purposes.

This island is probably better watered than any other one of the group. There are several large springs on the plateau, the water from which is piped down to the settlement, located at an elevation of 900 ft. Sufficient water is obtained in this way to supply a settlement of about four hundred and fifty people, and to run a large sugar mill. Streams also occur on the lower parts in the vicinity of Wreck Bay, during the rainy season, some of which have a considerable amount of water in them at times. The plateau is covered with a heavy coating of yellow clay-like soil which is mixed with vegetable mold in the wooded areas. This island was visited from Basso Point, Sapho Cove, and Wreck Bay.

Basso Point.

Basso Point is on the west side of the island about five miles northeast of Wreck Bay. The point shelters a broad bay which lies southwest of it, around which there are sand beaches and rocky shore. The sand beaches support a few halophytic plants and in the immediate vicinity of these beaches there are thickets of bushes of Cryptocarpus pyriformis, Discaria pauciflora, and Maytenus obovata. The country in the interior is quite rough and there are many exposures of lava on which there is scarcely any vegetation. The country rises gradually to an elevation of about 1,100 ft. above which the ascent is more abrupt, leading up to the top of a range of hills which run parallel with the coast in a northeasternly direction.

There are low dense forests on this part of the island which are made up mostly of trees of Bursera graveolens and Piscidia Erythrina, both of which are smaller than they are in the region around Wreck Bay. There is not as much cactus here as is usually the case in the lower regions. Cereus galapagensis occurs to some extent near the shore but no specimens of Opuntia were seen below an elevation of 800 ft., and they were not abundant even there.

There is a heavy growth of bushes in the forest in most places the most common species of which are: Croton Scoulera var. albescens, Discaria pauciflora, Gossypium barbadense, and Lantana peduncularis. The Discaria bushes grow so thickly in places as to form impassable barriers by the interlocking of their thorny branches.

This part of the island was not visited above an elevation of 900 ft. With the exception of a few specimens of Polypodium squamatum, all of the other plants which occur at this elevation grow abundantly lower down. Apparently the same sort of vegetation continues to the base of the hills mentioned above, about 200 ft. higher. The northwest sides of these hills are covered with forests, apparently made up largely of Scalesia trees. The southeast sides are treeless, however, as was noticed from the settlement near Wreck Bay, later in the season.

Sappho Cove.

Sappho Cove is also situated on the west side of the island about four miles northeast of Basso Point. The bay is small and almost entirely land-locked, but owing to the fact that it is very shallow, only small vessels can anchor in it. The shores surrounding the bay are made up of basaltic lava and sand beaches on which there are small groves of trees of Rhizophora Mangle and thickets of Laguncularia bushes in places. A short distance back of the beach in the vicinity of salt water pools, there are trees of Avicennia officinalis. The sand in the vicinity of the pools, and on the beaches, is covered in places with a heavy growth of Batis maritima, Sesuvium Portulacastrum, and Sporooblus virginicus. In several places along the open coast, in this vicinity, the sand has been thrown up into long ridges, as a result of the action of wind and waves. These ridges are covered, on the side next to the land, with a heavy growth of Conocarpus erectus, Cryptocarpus pyriformis, Discaria pauciflora, Maytenus obovata, Scaevola Plumieri, and Vallesia glabra. The roots of these bushes prevent the sand from shifting inland too rapidly.

The country is very flat between Finger Point and Sappho Cove, and is covered with beds of basaltic lava. In the immediate vicinity of the cove this lava is covered with a tolerably dense growth of xerophytic vegetation which gradually becomes thinner farther north until it is practically bare in the vicinity of Finger Point. As the vegetation decreases in amount it also becomes smaller, and such species as Bursera graveolens, which grow to the size of trees around Sapho Cove and further south, are mere bushes as Finger Point is approached. This place illustrates the gradual invasion of lava by higher plant life better than any other visted upon the islands. The most common plants on the lava beds here are: Aristida subspicata, Borreria ericaefolia, Bursera graveolens, Cardiospermum corindum, Cassia picta, Cereus galapagensis, Coldenia Darwini, Cordia galapagensis, C. lutea, Cryptocarpus pyriformis, Discaria pauciflora Euphorbia articulata, E. viminea forma chathamensis, Gossypium barbadense, Lycopersicum esculentum var. minor, Mollugo gracillima, Pectis tenuifolia, Phoradendron Henslovii, Polygalla galapagensis var. insularis, Porophyllum ellipticum, Scalesia divisa, Tephrosia cinera, and Waltheria reticulata forma intermedia. All of these plants grow from the crevices of the lava in which there is usually no appearance of soil at the surface.

The country south of Sappho Cove is covered with much older lava than is the country north. This lava is very rough in places and has deep fissures in it. The lower parts here are covered with a dense growth of xerophytic vegetation, very similar to that found in the vicinity of Basso Point, except that many trees of Hippomane Mancinella are found around an elevation of 500 ft. These trees usually grow along what appeared to be an old stream bed, as there were water-worn boulders in it. There are several small craters near an elevation of 800 ft., covered with forests of Bursera graveolens, on which there was an abundance of fruticose lichen.

Wreck Bay.

Wreck Bay is a rather open sheet of water, somewhat protected by reefs, which is situated at the southwest end of the island, and is the port for the settlement in the interior. The shores around the bay are composed of steep sand beaches, and low cliffs of lava. The country is low for some distance back of the shore, and it is probably of marine origin. There is a moderately steep ascent at the end of the flat area near the shore, which leads up to a broad plain, covered with masses of lava and soil which slopes gradually upward towards the interior to an elevation of 500 ft. There are a few small lava hills and craters at various places on this plain. There is rather a steep slope from 500–800 ft. elevation which leads up on to the rolling plateau region covering the central portion of this end of the island.

The settlement is located on this plateau at an elevation of 900 ft. There is a considerable amount of land under cultivation surrounding the settlement, on which coffee, and sugar-cane are produced. There is also a large garden in which many of the common vegetables and tropical fruits are grown. The products of the settlement are shipped to Gyayaquil, Ecuador, by means of a small schooner which usually makes monthly trips to the mainland. The plateau region has several high hills and craters on it.

There are no distinctly halophytic plants around the bay so far as was observed. The beaches here are too steep and the wave action at times is so strong that such plants would hardly be able to maintain a hold. The flat back of the beach is covered with Prosopis trees and bushes.

The country is covered with low dense forests below an elevation of 600 ft., which are made up mostly of trees of, Bursera graveolens, Piscidia Erythrina, Psidium galapageium and Zanthoxylum Fagara. In many places in the forest there is a dense growth of bushes under the trees, which are mostly of the species usually found on the lower parts. Places occur in the forest, however, where the trees are so closely arranged that there is very little undergrowth. On rocky hills and craters, in the lower part of this region, there is a considerable growth of Cereus galapagensis. In low places along the side of the road leading to the settlement there are also low groves of Hippomane Mancinella trees. On the steep slopes between 600–800 ft. elevation there are fewer trees and more bushes than lower down. The bushes that are commonly found here are: Croton Scouleri var. grandifolius, Clerodondron molle, Lipochaeta laricifolia and Psychotria rufipes. In some places on these hillsides, however, there are small trees of Scalesia pedunculata, and Hippomane Mancinella, the last of which is sometimes covered with Tillandsia insularis. Many of the bushes disappear higher up and those that remain are very much scattered. There is a heavy growth of grasses and sedges in this region consisting of the following species: Cyperus rubiginosus, Digitaria sanguinalis, Leptochloa virgata, Panicum geminatum, Scleria pterota, Setaria setosa, and Stenotaphrum secundatum. Ferns which occur in shady protected places in this region are: Asplenium formosum, A. sulcatum, Doryopteris pedata, and Dryopteris furcata. The plateau region above 800 ft. elevation is covered in most places with grasses, the most common species of which is Paspallum conjugatum, while in low and protected places there are a few trees and bushes. In temporary pools of water, formed during the rainy season, such aquatic and semiaquatic plants as Azolla caroliniana, Eleocharis capitata, E. fistulosa, Jussiaea repens, Lemna minor, and Polygonum acre are found. There are hedges of coffee and lime trees, near the settlement, and occasionally one of these is found in the open country, probably an escape from cultivation. There are also deep ditches which were evidently dug at an earlier day to take the place of fences. These have become filled in many places with a heavy growth of bushes of Miconia Robinsoniana, and on the moist perpendicular walls of the ditches there are many small ferns.

The plateau rises gradually in a northeasterly direction, attaining an elevation of 1,700 ft. at the base of the main mountain. Around the base of this mountain there are extensive brakes of Pteris aquilina var. esculenta, and in protected places, similar brakes of Gleichenia linearis and small trees of Telanthera rugulosa occur. The sides of the main mountain, which rises 400 ft. above the plateau, are covered in many places with a heavy growth of Lycopodium clavatum and ferns. On the leeward side of the mountain and other protected places, this growth is 2–3 ft. high, but where exposed to the constant action of the wind, it is usually much lower. Occasional tree ferns, Hemitelia multiflora also occur on the side of the mountain. Other plants common here are: Cyperus grandifolius, Hibiscus diversifolia, and Polygonum galapagense. Exposed places near the top are covered with Sphagnum, while at the top there are a few bushes and ferns. The soil and rocks in this region are covered with lichens, associated with which are large gelatenous masses which are probably Nostoc colonies.

A good general view of the plateau region was obtained from the top of this mountain. Except in ravines and other low places, it is covered with an unbroken stretch of grass-land from the northeast side around to the south side. On the remaining sides there are occasional trees scattered over the grassland.

All of the lower part of the island, that is covered with forests in the vicinity of Wreck Bay, seems to constitute the dry region. This extends up to about 650 ft. elevation, above which the transition forms a narrow belt extending to the grassy region which begins at 800 ft. elevation. The transition region here is more of a transition from woodland to grassland than from a xerophytic to a mesophytic vegetation. The moist region is apparently not well represented here unless we accept certain small areas, where local conditions are such as to permit a heavier growth of vegetation, as representing this region.

Culpepper Island.

Culpepper is located farther north than any other island in the group, and it is also one of the smaller of the islands. Deposits of basaltic lava, and tufa make up the island and form perpendicular cliffs along its sides. The cliffs descend directly into the sea and render landing impossible except at one place on the north side where they have become broken down and formed a large mass of talus. A gently rounded plateau covers the unper part of the island and has an elevation of several hundred feet. This plateau is inaccessible but is heavily covered with vegetation, which appeared from the vessel to be composed mostly of Bursera trees and Croton bushes. In addition to the above, there are a considerable number of small bushes, very similar in size and appearance to Scalesia Snodgrassii, which occurs on Wenman Island about twenty miles to the southeast. Thickets of a species of low Opuntia also occur here. On the talus slope, near the landing place on the north side, a few bushes, of Croton Scouleri var. brevifolius, and Telanthera Helleri occur. Bright red patches of vegetation were seen at various places along the sides of the cliffs a short distance above the water. These are probably composed of Sesuvium Edmonstonei as it forms similar patches elsewhere. One member of the party reported having seen the remains of sedges, the first time that these plants have been reported from this island.

Daphne Island.

Daphne Island is a small tufa crater, about half a mile in diameter, and 200 ft. high, which is located five miles north of Indefatigable Island. The sides of the island are steep, and with the exception of a few small trees of Bursera graveolens, there is but very little vegetation on them. The only plants collected here were: Abutilon crispum, Euphorbia amplexicaule, and Tribulus cistoides, all of which were taken by Mr. F. X. Williams from the inside of the crater.

Duncan Island.

Duncan is a small island, about three miles in diameter, which lies between Albemarle and Indefatigable Islands. The shores are steep and are made up of tall cliffs on all sides but the north and northeast. There is a small cove on the northeast side, sheltered by a small islet, which affords a good landing place for boats. Good anchorage can be obtained off the mouth of this cove, but as none is marked on the charts of these islands, vessels should take soundings from a small boat before attempting to come to anchor here.

The sides of the island are steep in most places, and all of the lower part is covered with loose fragments of lava among which there is a scanty soil. There are two old craters in the central part of the island which directly join one another there being no distinct rim separating the two. The crater to the north is the smaller, and its side walls are very steep and redish in color as is the soil which covers its floor. The southern crater forms a broad basin the floor of which is 850 ft. above sea level, and 400 ft. above the floor of the northern crater. There are some irregularities in the floor of the larger crater, but the most of it forms a rather flat plain, with occasional low places in it, some of which appeared to have been recently filled with water. There is a considerable amount of soil in this crater, which is light gray in color and loose in texture.

There is a high ridge to the east of the larger crater which in one place attains an elevation of 1,300 ft., the highest point on the island. The west side of this ridge is steep and there are cliffs in some places of a considerable height. The east side of this ridge is not so steep, however, but slopes downward to the tops of the cliffs along the eastern shore of the island. The upper part of this ridge is irregular and is covered with soil in places made up of disintegrated lava and vegetable mold.

Halophytic plants are but poorly represented on the island, and so far as was observed, consist of a single tree of Avicennia officinalis, a few Laguncularia bushes, and a few small stunted trees of Rhizophora Mangle, all of which grow at the end of the cove on the northeast side of the island. Sesuvium Edmonstonei also occurs here but not under halophyitc conditions. It is found in various places on the northeast side of the island to an elevation of 450 ft.

Unfortunately we were not able to get to this island during the rainy season, so at the times we visited here the vegetation was in the resting condition. The lower parts had more the appearance of a winter landscape in temperate region than that of a region within only a few miles of the equator. With the exception of the few mangroves, which grow near the shore, there was no other green vegetation worth mentioning. There were no trees of any kind, even the Bursera trees, which occur so abundantly in dry places on the most of the other islands, were entirely absent. This part of the island is covered with open thickets of bushes consisting of Cordia lutea, Gossypium barbadense, Lantana peduncularis, and Prosopis dulcis. Opuntia galapageia occurs abundantly above 450 ft. elevation, on the northeast side, but it appears to be almost absent from the north side. The branches of this species are more loosely arranged than usual, and the plants have a rather sickly stunted appearance. Those which occur high up on the island are often heavily covered with fruticose lichens as is the most of the other vegetation in this region. The vegetation thickens up considerably around 500 ft. elevation, on the north and northeast sides, and consists mostly of Croton bushes.

The east side of the island is very rough and covered in places with long ridges of rough broken lava, many of which extend down nearly to the tops of the cliffs above the sea. The vegetation on these parts consists mostly of Croton and Prosopis bushes to an elevation of 750 ft. Above this elevation the vegetation is more open, however, and there are areas which are covered with small plants, and occasional bushes of Acacia macracantha, Prosopis dulcis, and Zanthoxylum Fagara. The south sides of many of the large lava boulders in this region are covered with Polypodium squamatum, while the north sides are bare. This is probably due to the fact that the south sides of these boulders are bathed by the moist winds during several months of the year, while the north sides are not. The south side of the island was not visited but from a high point it appeared to be covered with a dense growth of bushes, many of which were covered with a brown colored epiphyte, probably a species of Frullania.

The interior of the smaller cf the two craters was not visied, but the inner walls appared to be covered with Croton and other bushes, all of which were heavily covered with lichens. The floor had a few bushes on it but the growth is not heavy enough to hide the soil in most places. The floor of the larger crater, to the south of the smaller one, is sparingly covered with Opuntia galapageia, and bushes of Prosopis dulcis, and Zanthoxylum Fagara. In low places around dried pools there was an abundant remains of Cyperus rubiginosus. The inner side of the ridge, to the east of this crater, is covered with a dense growth of Zanthoxylum and other bushes all of which were covered with lichens and leafy Hepaties. Along the top of this ridge, above an elevation of 1,200 ft., there were bushes and small trees of Acnistus ellipticus, Chiococca alba, Croton Scouleri var. brevifolius, Erigeron tenuifolius, Pisonia floribunda, Scalesia Baurii, Tournefortia psilostachya, T. Pubescens, and Zanthoxylum Fagara. Exposed rocks in this region are often covered with a thick growth of ferns which have formed a considerable amount of vegetable mold upon them. Tillandsia insularis, and two epiphytic species of ferns, Polypodium lanceolatum, and P. lepidopteris occur to some extent upon the bushes in this region. Several grassy areas extend down the east side from the top of this ridge on which there are also small specimens of Opuntia galapageia.

No large trees occur around the top of this island, although Pisonia floribunda, and Zanthoxylum Fagara, which grow here, usually attain the size of large trees at similar elevations on the other islands where these species occur. The absence of large trees is probably due to the strong winds which strike the top of the island during a greater part of the year, and thus prevent the growth of large vegetation.

Botanical regions are not well marked here but practically all of the plants which occur below an elevation of 900 ft. are forms typical of the dry regions, above this elevation many of the plants commonly found in the transition region make their appearance.

Gardner Island, Near Charles Island.

This island is situated about four miles off the east side of Charles Island. It is the smaller one of the two Gardner Islands, which occur in this group, and consists of an immense mass of lava several hundred feet high. The shores are steep in most places and are made up of tall cliffs some of which are perpendicular. Landing is dangerous, and can only be done with safety when the surrounding water is comparatively still.

The writer did not land upon this island so that the only plants collected were by other members of the party. They are few in number and in no way represent the entire flora. The island appeared from the vessel to be covered with low bushes which had a grayish color similar to those found on the lower parts of the most of the other islands. There were many specimens of a low species of Opuntia. Lichens seemed to be abundant on the vegetation.

Gardner Island, Near Hood Island.

This one of the Gardner Islands is situated about a mile off the north shore of Hood Island. The water in Gardner Bay, between the two islands, is quite shallow, so it is likely that the two islands have been connected at some past time. The island is quite small, and is made up of very old lava, some of which has broken down in places forming a light covering of soil mixed with small lava fragments. The east and south sides are rather flat and sand beaches occur along the shores on these sides. The remainder of the island is rough, however, and the shores are bordered by tall cliffs. A small bay is surrounded by these on the north side.

Low bushes of Cryptocarpus pyriformi occur in several places near the shore. The only trees on the island are those of Bursera graveolens and Opuntia galapageia. Bushes of Cordia lutea, Lantana peduncularis, and Prosopis dulcis are quite common.

Hood Island.

Hood is the most southern island of the group, being located five miles further south than Charles Island, thirty-six miles west of it. It is also one of the smaller and lower of the islands as its greater diameter is about eight miles and its highest point has an elevation of 640 ft. So far as was observed, the shores are high and rocky on all sides but the northeast where there are long stretches of sand-beach and low rocky shore. The sides slope up gradually from the shore at Gardner Bay, to a somewhat flat central region on which there are several rocky hills,, some of which rise possibly a hundred feet above the surrounding country. There is no distinct crater on this island. There is, however, a broad flat plain, about half a mile south of Gardner Bay, which may be the floor of a crater, the surrounding hills being all that is left of the rim.

The highest point is towards the southwest side of the island, and consist of a flat-topped hill of lava. A considerable amount of soil occurs in various places which has resulted from the breaking down of the lava. The most of the soil has probably been washed from above as it usually occurs in low places. The most of the isalnd has but very little soil on it, and the surface is strewn with fragments of lava.

The beaches are rather steep here in consequence of which there is not a great amount of halophytic vegetation. Bushes of Cryptocarpus pyriformis occur on the sand beaches, and at various other places near the shore. Patches of these bushes form about the only green vegetation during the greater part of the year, and they stand out sharply when the island is examined from the top of one of the hills in the interior. Sesuvium Edmonstonei grows here but usually not under halophytic conditions. The mangrove vegetation is confined to a small thicket of bushes of Rhizophora Mangle which occur on the northeast side of the island below Gardner Bay. The beach, in the vicinity of these mangroves, was strewn with pieces of bamboo, cocoanut husks, and other drift, showing that this area receives a more or less constant supply of such material.

Other plants which occur on or near the beaches are: Cacabus Miersii, Cenchrus distichophyllus, Coldenia fusca, Discaria pauciflora, Maytenus obovata, and Vallesia glabra.

The only trees of any size on the island are those of Bursera graveolens and Opuntia galapageia. The Opuntias have rather low thick trunks and closely arranged branches. Goats, which have been introduced upon this island within the last few years, eat off all of the lower Opuntia branches, and they even eat into the thick trunks in some instances. As these plants form their only suitable food and probably their only source of water, for several months of the year, there is danger of this species being exterminated on this island in time.

The most of the vegetation on the island consists of bushes, the most common of which are: Acacia macracantha, which forms small trees in protected places, Cordia lutea, Croton Scouleri, Gossypium barbadense, Lantana peduncularis, Parkinsonia aculeata, and Prosopis dulcis. These bushes occur in patches in many places in between which there are open spaces which are probably covered with grasses and annual herbaceous plants during the rainy season. By following these open spaces one can travel over the most of the island without much difficulty.

There are some indications of a greater amount of moisture around 600 ft. than lower down, as Polypodium squamatum grows from the lava crevices at this elevation. There are also a considerable number of small trees of Zanthoxylum Fagara in this vicinity which is near the base of the high hill on the southwest side of the island. The top of this hill is covered with bushes of Cordia galapagensis, Cryptocarpus pyriformis, Lycium geniculatum, Tournefortia psilostachya, and Vallesia glabra. Ipomoea Habeliana covers the rocks here to a considerable extent.

Indefatigable Island.

Indefatigable is the second largest, and with the exception of Duncan, is the most centrally located island in the group. It is roughly circular in outline, and appears to have a large central crater when seen from the south side. There is probably no larger crater present, however, because in sailing around the island towards the west side it is seen that the upper part is covered with many small craters, twenty-one of which were counted. Small lateral craters also occur at various places along the sides, the largest one of which is on the southeast side of the mountain a short distance below the top.

The shores along the south, southeast, and east sides of the island are bordered by low rocky cliffs of lava in most places, while on the other sides the shores are low with occasional sand beaches. There is a large bay on the south side which we christened it Academy Bay in honor of the California Academy of Sciences.

The sides of the island slope up very gradually on all sides so that it is necessary for one to travel several miles inland in order to get into the region where collecting is good. All of the lower parts are covered with the usual xerophytic forms so common on these islands, but which are not in proper condition for collecting through a greater part of the year. The lower parts are covered with lava on which there is but little soil, but in the interior there is an abundant soil, and in places there is said to be water, although we were not fortunate enough to find it. The interior of this island is very fertile, and with proper cultivation is capable of supporting quite a large population, but up to the time we visited it no attempt had been made to establish a settlement there.

We visited the island at Academy Bay, at two places on the north side, the northeast side, the northwest side at a point a little south of Conway Bay, and on the southeast side.

Academy Bay.

Academy Bay is a small body of water, partly surrounded by cliffs, on the south side of the island. It is marked by a small islet which lies on the east side of the entrance. Small vessels can find good anchorage in this bay but care should be taken in anchoring in the western part of it as there are hidden rocks present there. This part of the bay is the best protected from the southeast swell, so we anchored there on our first visit to this place, and were unfortunate enough to get aground on two occasions. The best landing place for boats is at the north end of the bay where there is a small sand beach, and a low flat area covered with bushes and grass, back of which there is an old trail leading into the interior. Two springs of brackish water occur here, each of which are marked by a bunch of small trees of Hibiscus tiliaceus. The country is very rough for a mile or more back from the beach and is covered with low ridges of lava, many of which run in a direction nearly parallel with the coast line. There are also many crevices in this lava, some of which are evidently quite deep. The lava has disintegrated but little on this part so there is very little soil to be seen on the surface, but nevertheless it is heavily covered with vegetation.

To the north of the rough area just mentioned, there is a line of cliffs, about 75 ft. high, above which the lava is evidently much older, as it has broken down in many places into soil, through which boulders of lava protrude at intervals. The amount of soil increases farther inland, completely covering the lava in most places above an elevation of 500 ft. The soil at this elevation, and above, is composed largely of vegetable mold which has been formed from the decay of the abundant vegetation in this region.

Small swamps of Rhizophora Mangle occur at several places around the shores of Academy Bay and around a small lagoon which empties into it. There are also clumps of Laguncularia bushes along the shore, and occasional trees of Avicennia officinalis around salt water pools in the vicinity of the shore. Back of the beach, at the north end of the bay, there is a small area that is thickly carpeted with Sporobolus virginicus. Thickets of Cryptocarpus bushes also occur here covered with Passiflora foetida. Occasional trees of Hippomane Mancinella also grow on this area. In many places along the west and south sides of the bay the growth consists of low bushes, with a considerable number of Cereus sclerocarpus and Opuntia myriacantha trees scattered among them.

After leaving the immediate vicinity of the shore, at the north end of the bay, one encounters dense jungles of xerophytic plants which extend inland a mile or more to the base of the cliffs mentioned above. This jungle is composed largely of trees of Acacia macracantha, Bursera graveolens, Erythrina velutina, Opuntia myriacantha, and Piscidia Erythrina. The specimens of Opuntia are very large, some of them attaining a height of thirty or more feet. In general it may be said, that nearly all of the species which occur in this area either attain a larger size, or grow more abundantly than they usually do so near to sea level. There is a dense growth of bushes underneath the trees consisting of Cordia lutea, Croton Scouleri varieties, brevifolius and Macraei, Discaria pauciflora, Gossypium barbadense, Lantana peduncularis, Maytenus obovata, Parkinsonia aculeata, Prosopis dulcis, Scalesia gummifera, Telanthera echinocephala, Tournefortia pubescens, and Zanthoxylum Fagara. Such ferns as Polypodium squamatum and Trachypteris pinnata grow on the sides of the cliffs at an elevation of 75 ft. Above these cliffs there is a considerable area which is covered with Prosopis and other bushes of an xerophytic character, but the arrangement of these is more open than below the cliffs. The trees of Opuntia myriacantha are numerous and very large in this area, and form a portion of the continuous zone of Opuntia trees which extend around the south side of the island. They are so numerous here that their redish-brown trunks give this color to the surrounding landscape when seen from a distance.

There is a general thickening up of the vegetation further inland, but there is not much change in the species of plants present below 350 ft. Around this elevation such forms as Cordia lutea, Croton Scouleri var. brevifolius, Discaria pauciflora, Opuntia myriacantha, Parkinsonia aculeata, Piscidia Erythrina, Prosopis dulcis, and Telanthera echinocephala disappear. The most of the vegetation, around this elevation, is heavily covered with fruticose lichens. There are dense forests here made up largely of trees of Pisonia floribunda, Scalesia pedunculata, and

Zanthoxylum Fagara, the first and last of which occur near the shore as bushes. The trees are often covered with a heavy growth of Cisampelos Pareira, which usually put down large numbers of aerial roots, forming tangled masses, rendering traveling difficult. Projecting ridges of lava occur in some places in this region, which are usually covered with dense mats of Polypodium squamatum, ands such herbaceous plants as Peperomia galioides, P. galapagensis, P. Stewarti, and other forms. The trunks and branches of many of the trees, especially those of Pisonia floribunda, are heavily covered with epiphytic plants such species as: Asplenium sulcatum, Ionopsis utricularioides, Lycopodium dichotomum, Polypodium lanceolatum, P. lepidopteris, Peperomia galapagensis, and Tillandsia insularis being the most common. Phoradendron Henslovii also occurs in this region and higher up, but it grows much larger than it does lower down. Owing to the dense shade there are fewer bushes, but more herbaceous forms than at a lower altitude. Ferns are also common.

The region above an elevation of 500 ft. on this side of the island consists of two distinct parts as far as the vegetation is concerned. The country immediately north of Academy Bay, above this elevation, is covered with dense forests which extend towards the east side of the island. In some places north of Academy Bay these forests probably begin a little lower down, but farther east they evidently begin somewhat higher, as they were not encountered at an elevation of 650 ft. when the southeast side of the island was visited. It might be said in this connection, that all of the botanical regions gradually ascend towards the east side of the island here, a condition which can be readily seen from the shore by the difference in color of the different regions. The forests, just mentioned, were not visited but from their appearance they must be made up largely of trees of Scalesia pednculata, and other species common in the Scalesia forests of these islands. Northwest of Academy Bay there are extensive areas covered with bushes on which there is a heavy growth of Argyreia tiliaefolia and other vines. The vegetation in this region was denser than in any other place visited upon the islands. Traveling was very slow and difficult here it being necessary at times to lift one member of the party up and let him fall at full length into the bushes and other vegetation in order to mash them down, for it was almost impossible to cut one's way through this vegetation, loaded down with water and food as we were. The principal bushes in this region are: Psychotria rufipes, Tournefortia rufo-sericea, Urera alceaefolia, and some others, the time spent in this region not being sufficient to make as complete collections as was desirable. There are many ferns and herbaceous plants in this region. Many of the herbaceous forms which occur here also occur lower down but are much smaller in size. The most noteworthy of these are: Crotalaria setifera and Fleurya aestuans, the last of which has fewer stinging hairs than at the lower elevations where it occurs. Groves occur occasionally in the bushy areas, made up of the trees usually found in the moist regions. Some of these groves are quite large, but usually they are small. Isolated trees are not at all uncommon.

No plants were collected above an elevation of 650 ft. on this side of the island, but other members of the party who succeeded in getting farther inland, report that there is a decrease in the number of vines and an increase in the size of the bushes higher up. Messrs. Williams, Ochsner, and Gifford succeeded in reaching an elevation of 1,100 ft. here, reported that the country, a short distance beyond where ther discontinued their journey, appeared to be covered with low spreading trees or bushes on which there was a large amount of "brown moss." A large part of the country, above the Scalesia forests, and bush areas, had a distinctly brown color in which there are patches of green. The brown color is possibly due to a heavy growth of one or several species of leafy Hepatics, and is confined to the south side of the island, none of it appearing on the other sides. The top of the mountain is covered with green vegetation, but it is likely that there are no trees present there, because none appeared in the sky-line when the top of the mountain was viewed with a field glass on a clear day.

As near as could be ascertained, the dry region extends to an elevation of about 350 ft., the transition region to 500 ft. while it is likely that the moist region extends to at least 1,500 ft. and possibly higher.

Judging from the appearance, the upper part of this island ought to be very interesting botanically, as it is apparently entirely different from the upper part of any other island visited.

It would probably require a week or more to explore this region properly, and in order to do this, it would be necessary to cut a good trail into the interior, and a camp established, where supplies of food and water could be brought in each day. It would probably be more economical to have this work done by laborers, as they could probably be secured from Albemarle Island at a small cost. Unfortunately our expedition was not financed in a way to make this possible.

Southeast Side.

The place visited on this side of the island, is situated about seven miles east of Academy Bay, the region just described. It is dangerous for vessels to anchor here, except during calm weather, as there is a strong swell at other times. We visited this place during the month of October, and were greatly inconvenienced by the violent rocking of the vessel at times. There are several hidden reefs between the anchorage and the shore, on which the swell breaks heavily at times. One has to use care in going in and out in a small boat when there is even a slight swell, because it is liable to break in unexpected places. A small crater stands near the shore at this place. Broad sand beaches border the shore, back of which there is a sandy basin containing pools of brackish water. There is supposed to be fresh water in this vicinity but we were unable to find it.

With the exception of a few ravines in the vicinity of the shore, the country is comparatively smooth for some distance inland, and is covered with a fair amount of soil. Farther inland, above an elevation of 200 ft., there are beds of more recent lava which has been piled up in places forming low ridges and valleys. Several small craters are located about four miles inland, between 400 and 500 ft. elevation, which rise on an average of about 100 ft. above the surrounding country. The country to the right of these craters is rough and covered with irregular masses of lava, while to the left it is comparatively smooth. The country was not visited beyond these craters, but it appeared from the top of the one fartherest inland, to have no pronounced irregularities in it as it sloped gradually up to the base of the craters in the central part of the island.

Rhizophora Mangle occurs in isolated patches along the shore, but there are no large swamps of it, probably due to the fact that the surf breaks here much of the time. Quite a number of other species of plants grow on the beaches among which are Coldenia Darwini, Cryptocarpus pyriformis, Heliotropium curassavicum, Scaevola Plumieri, Sesuvium Portulacastrum, and Vallesia glabra. The low sandy area back of the beach is covered in some places with a heavy growth of Sporobolus virginicus, while in other places, where the sand is encrusted with salt, Ipomoea Pes-caprae grows very abundantly and of great length, individual plants sometimes being fully one hundred feet long. Cyperus laevigatus is very common around the pools of brackish water, which have a strong odor of Sulphurated Hydrogen. Bordering this sandy area are low dense groves of Avicennia officinalis, Hippomane Mancinella, and Laguncularia racemosa. There are several other low areas and ravines in the vicinity of the shore, above high tide mark, which are filled with thickets of Discaria pauciflora, and Parkinsonia aculeata. The remainder of the lower part of the island at this place is covered with bushes, Bursera trees, and cactus. Cereus sclerocarpus occurs commonly in the vicinity of the shore but was not seen above an elevation of 100 ft. Opuntia myriacantha, on the other hand, occurs abundantly on the lower parts, and to a considerable extent to about 500 ft. At an elevation of 600 ft., however, it is scarce, and much smaller than lower down. The specimens seen at this elevation, were of about the same size as those which occur at an elevation of 350 ft. at Academy Bay a few miles west of here. The Bursera trees are larger and more abundant above an elevation of 350 ft. than they are lower down. They are usually heavily covered with fruticose lichens. Piscidia Erythrina is another common forest tree in this region.

There is a very noticeable decrease in the number of many of the forms common on the lower parts, between 350 and 450 ft. elevation. Some of the species disappear here among which are: Croton Scouleri, Discaria pauciflora, Maytenus obovata, and Telanthera echinocephala. A few stunted specimen of Cheilanthes microphylla were found in the lava crevices at an elevation of 350 ft., and were the first ferns ever collected on this island.

There are fewer trees in the region of the craters, at 400 ft., elevation, than lower down, and the country is covered with Lantana bushes four to five feet high with a few trees scattered through them. The sides of the craters are covered with low bushes of Euphorbia viminea, and other species, while at the top there are bushes, ferns, and grasses. The country to the north of these craters, is heavily forested with Bursera and other trees, under which there are tangled thickets of Zanthoxylum bushes.

Low forests cover the country between 450 and 650 ft. elevation, which are made up of a mixture of xerophytic and mesophytic forms. Bursera trees are common on the lower part of this area, but they decrease in number higher up, where the forests are composed largely of Pisonia floribunda, Psidium galapageium, and Scalesia pedunculata. The Scalesia trees are smaller, and fewer in number here than they are in the Scalesia forests higher up. Quite a number of ferns grow in the vegetable mold, and on exposed rocks in this region, such species as Polypodium pectinatum, P. squamatum, and Trachypteris pinnata being the most common. A few epiphytes grow on the trees and bushes among which are: Ionopsis utricularioides, Peperomia galapagensis, Polypodium lepidopteris, and Tillandsia insularis. Common bushes in this region are: Chiococca alba, Erigeron tenuifolius, Gossypium barbadense, and Tournefortia strigosa. The region above an elevation of 650 ft. was not visited, but it appeared to be covered with Scalesia forests a short distance above this elevation.

The dry region extends to an elevation of about 400 ft. at this place. We did not reach the upper limit of the transition region, but as near as could be estimated, it extends to about 800 ft., the elevation at which the Scalesia forests probably begin.

No effort was made to get far into the interior at this place, as we made our first visit to the island here, and expected to find better places for doing this elsewhere later in our trip. After having failed to accomplish this at other places, it now seems probable that this would have been the best place to have made the attempt after all. It is very likely that one would have no difficulty in reaching the lower edge of the Scalesia forests in a half day's journey, if no collecting were done on the way. From this point it is probably not over three or four miles to the base of a large lateral crater, on the southeast side of the mountain just below the top. Judging from its appearance, this crater would present about the same botanical conditions as occur around the top of the mountain. The advantages to be gained from exploring the interior of the island from this side are; the slope is not so gradual, so that elevation could be gained by traveling shorter distances, and, there are heavy forests in the moist region which would probably have less undergrowth in them than the bushy areas encountered in this region at Academy Bay. Should another party ever attempt to reach the interior of the island from there, they should keep well to the south of the group of craters, about four miles inland, as the country is not so rough, nor is the vegetation so dense as it is north of these craters. A low monument of lava boulders was built by the side of the trail where we came into it in coming back from the interior. It is likely, however, that the trail will be entirely obliterated before another party attempts to explore this island.

Northeast Side.

The island was visited on this side at a point about three miles west of Gordon Rocks which are situated a short distance off shore. The coast is bordered by low cliffs in this vicinity, which rise abruptly fifteen or more feet above the water. There are occasional small sand beaches, however, so that landing from boats can be easily accomplished. The country is very flat for some distance inland, and for the most part, is covered lightly with a reddish colored soil. Farther inland there are rough deposits of lava. We had expected to try to reach the interior of the island from this place,- but we did not attempt it after we had discovered the rough character of the country.

There are no true halophytes along the shores in this vicinity, a condition that is accounted for by the lack of extensive sand beaches, such as occur on the other sides of the island where there is a more or less extensive halophytic flora. Such plants as Cryptocarpus, pyriformis, Discaria pauciflora, and Maytenus obovata, which sometime grow under semihalophytic conditions, occur, however, at this place.

The country is very barren in the vicinity of the shore, and there are no trees present unless a few stunted specimens of Bursera, and Prosopis could be called such. The country farther inland, however, appeared to be covered with forests of Bursera trees, but as we visited this region during the dry season, the general appearance of these forests was too uninviting to tempt one to venture far to examine them. All of the vegetation of any considerable size, leans in a northwestern direction showing the influence of the strong southeast winds during the growing season. The strong winds, and the loose character of the soil, are the probable causes for the small amount of vegetation here. The ground in most places is covered with a sparse growth of grass, the two common species of which are, Aristida subspicata, and Panicum hirticaulum.

North Side.

The shores along the north side of the island are made up of sand beaches and low rocky coast, which in most instances slope down gradually to the edge of the water. There are but few cliffs along the shore on this side, a condition that is probably due to the fact that this is the leeward side of the island and is consequently not subject to strong wave action as are the more exposed sides.

For a considerable distance inland the country is flat and covered in many places by beds of basaltic lava on which there is but little soil. There are small areas, however, which are covered with a light gray ashy soil in among the deposits of lava. Rough lava ridges are common, and there are several low lava-hills, and small craters scattered around at various places on this side.

The sand beaches for the most part bear the usual herbaceous plants, and in the vicinity of the shore thickets of Cryptocarpus pyriformis, and Vallesia pubescens bushes are common. Bushes of Maytenus obovata line the shore in places, some of which grow so close to the water's edge that their roots are covered at high tide. In such places the trunks are more gnarled, and the leaves more succulent than is usually the case. Mangrove swamps occur in several places, the largest one being located about two miles west of the lower end of South Seymour Island. So far as was observed this is the most typical mangrove swamp on the islands. A shallow bay occurs here which has a narrow opening into the sea and affords much quieter water than in most places on these islands. There are several small islets in the bay, and these as well as the shores of the bay are heavily covered with mangroves. One is able to get through the swamp in a small boat by following the deeper channels at high tide. We found it to be an excellent place for capturing sea turtles. Trees of Avicennia officinalis and Laguncularia also occur in this swamp, but Rhizophora makes up the bulk of the vegetation. All three species occur at various other places along the north shore, and Avicennia was found in one instance to be growing in a sunken place, a short distance inland, which was apparently filled with sea water at high tide.

The interior is barren in many places where there are exposures of lava. With the exception of a few low stunted trees of Bursera graveolens, a low Opuntia, and scattered bushes these beds bear no other vegetation. The species of Opuntia is possibly a new one as it differs quite markedly from the other species in this genus which occur on these islands. It also occurs on South Seymour Island, a few miles away, but at neither place were the specimens in good shape at the times these were visited. Occasional bushes of Acacia macracantha, and thickets of Croton bushes occur in small patches between the lava beds, where there is a sufficient amount of soil to support them. Grassy areas occur, between the patches of bushes, which are usually covered with Aristida subspicata. These areas continue at intervals, to an elevation of 1,000 ft. as high as this side of the mountain was explored. Very little change takes place in the character of the vegetation at this elevation, except that some of the species grow to a larger size than they do lower down. This is especially true of Bursera graveolens, and Piscidia Erythrina, both of which are quite small near the shore but form trees in the interior.

The dry region extends to possibly an elevation of 1,500 ft. on this side of the mountain, as the appearance of the vegetation did not appear to change for several hundred feet above where exploration was discontinued. The moist region seems to form a narrow zone just below the top on this side of the mountain.

Northwest Side.

This side of the island was visited at a place about two miles south of Conway Bay, which is marked by a small tufa crater near the shore. Our reason for stopping here instead of at Conway Bay, the usual place for landing on this part of the island, was because we had learned at Chatham Island that an old trail led into the interior from this point.

The coast is low in this vicinity, and is made up of sand beaches and low cliffs. A flat area surrounds the tufa crater, mentioned above, covered with a soil composed largely of volcanic ashes, which have evidently originated from the crater. This condition is local, however, as the most of the soil on the lower parts is composed of disintegrated lava with small boulders and bits of lava intermixed. There are also lava ridges in this vicinity without soil.

The slope is very gradual to 700 ft. and in places the country is slightly terraced. Above this elevation the ascent is quite steep to 1,000 ft. beyond which there is a broad valley, three or four miles wide, extending in to the base of the craters on the west side of the island. There is a heavier growth of vegetation here than on the north side of the island, probably due largely to the fact that there is more soil.

About the only vegetation on the beach, where we landed, was a sparse growth of Sporobolus virginicus, but back of the beach around the base and on the sides of the cliffs there were bushes of Cryptocarpus pyriformis, Discaria pauciflora, and Maytenus obovata. Grassy areas occur back of the shore, where the soil is composed of ashes, which at the time of our visit were covered with a heavy growth of Aristida subspicata. There is probably quite a growth of annual plants in addition to the above, during the rainy season, as the remains of quite a number of these were found. Patches of bushes occur in the grassy areas which are made up of such species as Acacia macracantha, Clerodendron molle, Cordia lutea, Croton Scouleri var. brevifolius, Gossypium barbadense, and Waltheria reticulata forma intermedia. Low trees of Bursera graveolens and Piscidia Erythrina occur among the bushes. A few specimens of Opuntia grow in the vicinity of the shore but whether or not these are O. myriacantha or the undescribed species from the north side of the island, was not determined, as no specimens were collected. They are more abundant farther inland.

The character of the vegetation changes but little to an elevation of 300 ft. except that the grassy areas soon stop and the country is covered with Bursera forests very similar to those on the lower parts of other islands. Trees of Erythrina velutina also occur here in considerable number. Cissampelos Pareira appears first at about 300 ft. elevation, but it becomes more abundant higher up where it often covers trees and bushes. A few of the more xerophytic species of ferns appear around an elevation of 400 ft. We experienced much difficulty with the thickets of Furcraea cubensis at an elevation of 450 ft. and above, as they often cover areas of several acres in extent in this region. This species was brought to this island many years ago by the tortoise hunters who made a temporary settlement here, and who introduced it among other domesticated plants. They were planted along the trail, leading into the settlement, by Captain Thomas Levick of Chatham Island, on one of his periodic visits to this place. He hoped to permanently mark the traii by this means, but judging from the difficulty we had getting around these thickets and finding the trail again, his method of marking it was rather too effective. They grow so thickly that they have driven out the smaller vegetation in places.

The country around 650 ft. elevation is heavily forested with trees of Bursera graveolens, Piscidia Erythrina, Pisonia floribunda, and Zanthoxylum Fagara. This forest is open in places and the ground is covered with occasional bushes and ferns. Above 700 ft. elevation the forms which occur abundantly on the lower parts, disappear. The forests above this are made up of large trees of Pisonia floribunda, Psidium galapageium, Scalesia pedunculata, and Zanthoxylum Fagara, the last of which forms trees 25–30 ft. high, usually heavily covered with mistletoe. The undergrowth is usually dense in these forests and is composed largely of bushes of Erigeron tenuifolius, Psychotria rufipes, Tournefortia rufo-sericea, and several species of ferns and herbaceous plants. Epiphytes are common, consisting of ferns and orchids, Ionopsis utricularioides. Conditions similar to the above, continue to an elevation of 1,000 ft. as high as this side of the island was explored. From a tree at this elevation, the country appeared to change but little for several miles further inland.

We visited this place during July, and as it was the last time that we expected to stop on this island, we made a rather determined effort to get farther into the interior than we had done before. We hoped to follow the trail in as far as the old settlement where it is reported that water can be found, and where there are a number of domesticated plants growing which are suitable for food. We expected to camp at the settlement and try to work inland from there. We lost the trail at 1,000 ft., however, and had to turn back as our supply of food and water was not sufficient to justify us in going farther. The only evidences of former habitation found, was a number of lime trees near where we lost the trail. We learned afterwards that these were but a short distance away from the settlement, but as everything was so overgrown with vegetation in this region, it probably would have been impossible for us to have found it unless the trail had led directly to it.

The botanical regions are fairly well marked here. The dry region seems to extend to about 450 ft. and the transition region to about 700 ft. elevation. The moist region seems to be evenly forested and has none of the open areas covered with bushes and vines, such as was found at Academy Bay on the south side of island.

JAMES ISLAND.

James, the fourth largest island in the group, is located nine miles northeast of Cowley Bay, Albemarle Island, and twelve mile north by west of Indefatigable Island. The general shape of the island is a parallelogram the length of which is about twenty miles, and extends east and west. With the exception of a few sand beaches, the shores are rocky and are bordered in most places by low cliffs of lava. The eastern part of the island is low, and slopes up gradually to a broad central plateau which extends, with a gentle slope, to the base of the main crater, located towards the west end of the island. This crater has an elevation of 2,850 ft., and can be more easily reached from James Bay than from any other point. Many other craters occur on the island, but with one or two exceptions, they are all small. There are a number of these in the vicinity of Sullivan Bay, and along the south side. Deposits of basaltic lava, and volcanic cinders, cover the greater part of the island, the most of which is quite old, and has become very much oxidized. In many places in the interior, it has become entirely broken down on the surfaces, into soil, which is mixed with quite a large amount of vegetable mold.There are, however, some very recent deposits of lava on the south side, some of which have recently come from a small crater which has been active within the last few years. Deposits of tufa occur on the west side, but they are very local in their distribution.

Northeast Side.

This side of the island was visited about six miles northwest of Sullivan Bay. There is a small salt-water lagoon here, apparently the only one on the island. The shores are low and rocky in most places in this vicinity, but short sand beaches occur occasionally. The country is covered with beds of rough basaltic lava and cinders all of which is very old and has become stained with a dark brown color. This lava has not become broken down to any extent, so consequently there is but little soil in this region. The ascent is very gradual here so that it is necessary to go about four miles inland in order to reach the plateau region, which covers the central part of the island. The eastern part of this plateau has a general elevation of about 700 ft., but it slopes up gradually, towards the west, to the base of the mountain. There is more soil on the plateau than lower down, but it is mostly in low places so that the surface of the ground is usually strewn with lava fragments. Several old craters are located on the plateau at an elevation of 700 ft., all of which are low in altitude.

The sand beaches support many of the smaller plants which are usually found in such situations on these islands. Among these are: Batis maritima, Cryptocarpus pyriformis, Discaria pauciflora, and Sporobolus virginicus. Rhizophora Mangle is the only one of the mangroves that grows on the open coast at this place. It also grows to some extent around the shores of the salt water lagoon, mingled in places with Avicennia officinalis. In the vicinity of the shore, the country is covered in places with thickets of Discaria, and Maytenus bushes, but there are no trees except those of Opuntia myriacantha. There are a few specimens of Bursera, but they are mere bushes, and do not grow to the size of a tree for some distance inland. The crowns of the Bursera trees are usually much flattened, due to the action of the wind. There are quite a number of species of bushes farther inland, all of which grow from the crevices of the lava. Among these are: Alternanthera rigida, Cordia lutea, Croton Scouleri var. albescens, Euphorbia articulata, and Scalesia atractyloides. With the exception of the halophytes along the shore, the Scalesia bushes were about the only plants that presented a green appearance at the time of our visit. There were many other plants in leaf at this time, but the leaves were either small, or covered with a dense coating of hairs so that the green color was obscured. There are small stretches of lava near the shore on which there is practically no vegetation.

The vegetation becomes more abundant between 100 and 200 ft. elevation where there are extensive thickets of Lipochaeta bushes, which also occur still higher up on this side of the island. This species is infested with Phoradendron Henslovii as are some other forms in this region and above. The vegetation is further added to, between 300 and 400 ft. elevation, by the appearance of small trees of Erythrina velutina, and thickets of Zanthoxylum bushes, the last of which apparently does not attain tree size on this side of the island. Opuntia galapageia occurs in this region and continues to above 700 ft. elevation.

The plateau, around 700 ft. elevation and above, is covered with much the same sort of vegetation as the lower country, except that it is thicker in places, and some of the species attain a larger size. No ferns or other distinctly mesophytic plants were found if occasional small trees of Pisonia floribunda be expected. The small craters on the plateau are covered with bushes, and trees of Cereus sclerocarpus and Opuntia galapageïa all of which have a considerable amount of fruticose lichen on them. A good view of the surrounding country can be had from the tops of these craters. The country to the south and east was barren in the extreme and appeared to be covered with much the same sort of vegetation which occurs in the region explored on the north side of the island. The country to the west appeared almost as uninviting, for possibly 700 ft. higher, and the vegetation all had the distinctly gray color characteristic of the dry regions of these islands. It was noticed, while we were sailing along the north shore, that similar conditions to the above are present nearly to the top of the mountain on this side.

James Bay.

The conditions at James Bay, at the west end of the island, were much more inviting than they were on the northeast side. A sand beach extends along the east side of the bay and affords a good landing place for boats the most of the time. The north side of the bay is bordered by cliffs, which rise in height towards the northwest and terminate in a tall perpendicular cliff about opposite Albany Island, which is situated a short distance off shore. The coast is rocky for some distance south of the bay, and is made of low up cliffs of recent lava. Back of the sand beach, just mentioned, there is a stretch of flat sandy country, in which there is a small salt water lake. The flat country extends to the base of the mountain which rises quite abruptly to an elevation of about 1,400 ft., beyond which the slope is more gradual, and the country is in the nature of a table land to the base of the main crater at about 2,200 ft. elevation. The sides of this crater are steep and the top has an elevation of 2,850 ft. To the south and southwest of the main crater there are deep valleys in between other craters and hills. The whole of the south side of the island is steep, above 900 ft. elevation, for several miles east of James Bay. Below this elevation, however, the slope is more gradual and the country is covered with recent flows of lava, the most of which has probably come from one or more of the small lateral craters around 900 ft. elevation. The lava fields are comparatively smooth near the shore, but higher up they become rough, and in places the lava has cooled enclosing gas bubbles with only a thin shell of lava above, through which one breaks in walking.

The region around Sugarloaf mountain, towards the southwest side of the island, is covered with tufaceous deposits, which have probably come from the tufa craters in this vicinity. One of the smaller tufa craters, encloses a salt water lake, on the bottom of which there is a layer of apparently nearly pure salt several inches in thickness. The people from the inhabited islands used to come here for their supplies of salt many years ago.

Except on the recent lava and on the steeper sides of the mountain, there is a considerable amount of soil to be found all over this part of the island. The soil is composed of disintegrated lava, which on the higher parts is mixed with vegetable mold. No springs occur on this island but there are a few small stream beds in the upper region, which appeared to have contained water at some time, as there were water-worn stones and pebbles in them.

There are but few halophytic plants on the sand beaches around James Bay. Batis maritima occurs in a few places and there is a considerable growth of bushes of Conocarpus erectus bordering the shore. A heavy growth of bushes and small trees surrounds the salt-water lake, just back of the beach, which consists of the following species: Avicennia officinalis, Cryptocarpus pyriformis, Discaria pauciflora, and Maytenus obovata. The remainder of the sandy area, at the base of the mountain, is covered with open woodland made up largely of trees of Bursera graveolens, and Erythrina velutina, the last of which were in blossom when we visited this place in December. There are also open grassy areas in the woodland covered mostly with Setaria setosa, bushes of

Telanthera echinocephala, and Lantana peduncularis. The last one of these also occurs on the north and south sides of the bay, where it often forms dense thickets five or six feet high, covered in shady places with vines of Asclepias angustissima, and Passiflora linearloba.

Except for an occasional bunch of Cereus nesioticus, and a few other plants, all of which occur in protected places, the recent lava beds south of James Bay, are practically bare of vegetation below an elevation of 500 ft. Along the edges of these beds, next to the older lava, however, there are thickets of bushes which are made up almost entirely of Scalesia atractyloides, which does not seem to grow in any other situations here. Borreria ericaefolia is another plant which is found in similar situations to the above, and also for some distance out on the lava beds. Above an elevation of 500 ft. there is a considerable amount of small vegetation on the recent lava, made up mostly of Asclepias angustissima, and Polypodium squamatum. This increases in amount with the ascent and at an elevation of 900 ft., there are small trees of Cereus sclerocarpus, and bushes of Dodonaea viscosa, and Lipochaeta larcifolia. Quite a number of ferns are to be found in the old craters and lava caverns around this elevation among which are: Asplenium, cristatum, A. formosum, A. sulcatum, Ceropteris tartarea, Nephrolepis bisserata, and N. pectinata. Many of the species which were common at a lower elevation, occur along the edges of the recent lava beds here, associated with such mesophytic forms as bushes of Erigeron tenuifolius var. tomentosus, and Psychotria rufipes, and trees of Pisonia floribunda. The presence of ferns and other mesophytic plants associated with such xerophytes as Bursera, and Cereus, indicates that the region around an elevation of 1,000 ft., on this side of the island, lies within the transition region.

There are several islands of vegetation on the lower part of the south side of the island which are surrounded by beds of recent lava. None of these were visited, but they appeared from a distance to be covered with the usual species found in the dry regions. Several small mangrove swamps occur along the south shore.

The tufaceous region in the vicinity of the Sugarloaf Mountain is covered with small Bursera trees, Croton bushes, and other dry-region forms. The Sugarloaf mountain is a large tufa crater with steep sides, which rises to a height of 1,200 ft. The sides of the mountain are covered with dry-region forms and apparently there is but little change in the character of the vegetation from the bottom to the top. The appearance of the mountain was so uninviting that the top was not visited. The interior of one of the smaller tufa craters in the vicinity of the Sugarloaf was visited, however, and a few halophytic plants, and trees of Hippomane Mancinella were found growing around the salt water lake in its interior.

The sides of the mountain east of James Bay are covered with forests, which to an elevation of 1,000 ft. are composed largely of trees of Acacia tortuosa, Bursera graveolens, Erythrina velutina, and a few trees of Hippomane Mancinella. The undergrowth is usually rather open in this region and is made up mostly of bushes of, Castela galapageia, Cordia lutea, Croton Scouleri var. brevifolius, Telanthera echinocephala, Tournefortia strigosa, and Waltheria reticulata forma intermedia. Occasional trees of Scalesia pedunculata begin to appear around an elevation of 1,000 ft., but they become larger and more abundant higher up. Ferns are found abundantly above 1,300 ft. elevation such species as Doryopteris pedata, Polypodium lepidopteris, P. pectinatum, and P. squamatum being the most common. Such epiphytes as Peperomia galapagensis, and Tillandsia insularis are also found. The undergrowth, which is made up largely of Tournefortia strigosa, becomes thicker than lower down.

The rolling plateau, which extends from 1,400 ft. to the base of the main crater at 2,200 ft. elevation, is covered with forests of Pisonia floribunda, Psidium galapageium, Scalesia pedunculata, and Zanthoxylum Fagara. The Scalesia trees are the most abundant in this region, and form true Scalesia forests, as on some of the other larger and higher islands of the group. The trees of Psidium galapageium are smaller than at similar elevations on other islands where this species occurs. Bushes of Tournefortia strigosa continue into this region and such other bushes as Brachistus pubescens, Croton Scouleri var. grandifolius, Erigeron tenuifolius var. tomentosus, Phytolacca octandra, Psychotria rufipes, Tournefortia rufo-sericea, and Urera alceaefolia are commonly found, especially towards the upper part of this region. There are many open areas, in the deeper valleys between the hills and craters, which are covered with a heavy growth of Paspalum conjugatum. In his Voyage of the Beagle, Darwin mentions that he found beds of Cyperus, on the upper part of this island, in which there was a species of water rail. The Ornithologists of the expedition succeeded in capturing several specimens of this rather rare bird, but in each instance they were found to be hidden in the thick growth of Paspalum grass, no beds of Cyperus having been found.

The forest trees, and bushes are heavily covered with epiphytes around 2,200 ft. elevation and above. Ferns are common among these, Polypodium aureum, and Nephrolepis pectinata being the most abundant. Other epiphytes worthy of mention are: Epidendrum spicatum, Lycopodium taxifolium, and Peperomia galapagensis, besides mosses and lichens. There are many species of terrestrial ferns in shady places and on moist banks. The Scalesia forests extend nearly to the top of the main crater on the leeward side, but on the windward side, which is bathed almost constantly by the strong southeast trade winds for several months of the year, the trees begin to thin out a short distance above the base of the crater and there are none at the top, although Zanthoxylum persists here as small gnarled bushes. Bushes of Psychotria rufipes are very common on this side and around the top. There are many ferns around the top, among which is Hemitelia multiflora, the only tree fern on the islands.

The top of this mountain was heavily covered with fog at the time it was visited so that no general survey of the surrounding region could be made. As near as could be determined the dry region extends to about an elevation of 1,300 ft. on this side while the transition region extends to possibly 2,000 ft. varying, however, at different places.

The steep sides of the mountain, above the lava fields on the south side of the island, are covered with the usual species found in the transition regions, a condition which extends up to above 1,600 ft. elevation. There are many ravines extending down this side, which broaden out occasionally and enclose park-like areas. In most places these ravines are filled with bushes and trees. Fruticose lichens are very abundant upon the vegetation here.

Jervis Island.

Jervis lies about four miles off the south shore of James Island. It is a small island, not over two miles in diameter, which rises to a height of 1,050 ft., in consequence of which the sides of the island are very steep. A pebble beach extends along a portion of the north side, near which there is a small salt water lake surrounded on the sides by a small area of level land. There are three peaks on the island which vary in height from 950–1,050 ft. The flat area near the shore is covered with dark red soil mixed with bits of lava, but the steep sides have very little soil on them, except in low places and in crevices of the lava. The sides in places are strewn with small lava boulders.

Low bushes of Cryptocarpus pyriformis grow along the beach, while around the lake there are small trees of Avicennia officinalis, and Laguncularia racemosa. Tangled thickets of Discaria pauciflora with very long stiff spines, and bushes of Maytenus obovata occur just above the lake on the side next to the land. There are many small trees of Bursera graveolens, and Opuntia myriacantha scattered over the lower part of the island. The first of these species gradually disappears higher up, while the second becomes very much reduced in size, appearing at the top in a more or less decumbent form. The steep sides of the island are covered with bushes which consist chiefly of Croton Scouleri, and Waltheria reticulata. All of the vegetation, above an elevation of 450 ft., is heavily covered with fruticose lichen indicating a somewhat greater amount of moisture than lower down.

The vegetation has a decidedly stunted appearance around the summit, and with the exception of a single species of fern, Polypodium squamatum, all of the other plants are distinctly dry-region forms. There are no trees at the top, and the bushes which occur there, are usually low and more or less prostrate.

Narborough Island.

Narborough, the third largest island in the group, is situated just west of Albemarle Island from which it is separated by a shallow channel about two miles wide at its narrowest point. The northern end of the island is nearly opposite Tagus Cove on Albemarle Island. A large crater, probably over 5,000 ft. in height is situated somewhat north of the center, and there is a gradual slope upward from the shore to the base of it on all sides but the north. The outer walls of the crater rise abruptly on the north side, and are almost perpendicular in places. There is a broad flat plain of old lava at the base of the crater on this side.

This island shows more evidence of recent volcanic activity than any other island in the group. The sides are covered in most places with deposits of basaltic lava and volcanic cinder which are practically bare of vegetation in most places. There are, however, occasional islands of older lava, which were not covered by the more recent flows, on which there is a considerable amount of vegetation. Some of these islands are quite large. One was visited on the north side, and was found to extend from the base of the crater to the shore, while on the east and west sides of it there were extensive beds of volcanic cinder of more recent origin. The older lava was deeply stained through weathering. There were occasional lava tunnels in the older lava, the tops of which had fallen in in places leaving openings into long narrow caverns high enough in places for one to walk through them in comfort. There was but little soil on this part of the island in consequence of which the vegetation was very scanty.

The island was visited for botanical purposes on the north, and northeast sides. The shores are bordered by low cliffs, along the north side, which are almost perpendicular in most places. On this account landing is difficult and even dangerous except in calm weather. As there is no suitable anchorage on this side, we visited it in boats, and it was necessary for one member of the party to remain in the boat and keep it off shore, while the remainder of the party did their collecting. On this account our stay here was more limited than it would have otherwise been.

Botanical conditions were very discouraging. There are no trees of any kind on this part unless the few small Burseras which occur here, could be designated as such. Neither Cereus or Opuntia is to be found although they both occur on the south side of the island. There is a scattered growth of bushes consisting of: Castela galapageia, Cordia Hookeriana, Euphorbia diffusa, Lippia rosmarinifolia, Scalesia narbonensis, and Waltheria reticulata forma intermedia. Vines of Asclepias angustissima, and Cissampelos Pareira were found to be growing on the bushes in places. Several species of grasses grow from the lava crevices among which are, Bouteloua pilosa, Cenchrus granularis, Eragrostis ciliaris, and Paspalum canescens. A single fern, Notholaena sulphurea, was found at an elevation of about 500 ft.

The part of the island visited on the northeast side, is about opposite Tagus Cove. There is a small bay at this place around which there are small mangrove swamps, as there are at several other places along the east and south shores of the island. Botanical conditions were even more discouraging here than they were on the north side, as all of the country in this vicinity was found to be covered with beds of recent lava on which there was apparently no other vegetation than occasional specimens of Cereus nesioticus and Cyperus Mutisii.

Mr. Beck succeeded in reaching the top of the mountain, when he visited the island from the south side somewhat earlier in the season. He reported it to be heavily covered with vegetation, among which were ferns and other mesophytic plants. He also reported a heavy growth of tall grass around the top, which from his description, must have been Pennisetum exalatum. There are two lakes inside the crater which are probably 2,000 ft. or more below the rim. The inner walls were covered with recent lava.

Seymour Islands.

The Seymour Islands, three in number, lie off the northeast corner of Indefatigable Island of which they probably formed a part some time in the past. The islands are all low and are separated from each other by relatively narrow and shallow channels. South Seymour, the only one of the three visited, is the largest and lies closest to Indefatigable from which it is separated by a channel about one half mile in width.

The shores of this island are steep and formed by low cliffs, except in two places on the west side, where there are sand beaches. One of these beaches borders a rather large bay which affords good anchorage for vessels. Back of this bay there is a flat sandy area of some extent, but otherwise the surface of the island is covered with large irregular boulders of lava in between which there is a scanty light red soil.

The densest vegetation on the island occurs on the sandy area mentioned above, where thickets of bushes made up of Cryptocarpus pyriformis, Discaria pauciflora, and Maytenus obovata are to be found. In front of these thickets, there is a considerable area along the beach which is covered with Ammophila arenaria, the only place on the islands where this species has been found. The remainder of the island is covered with small

Bursera trees, bushes of Castela galapageia, Gossypium barbadense, small specimens of Opuntia, Parkinsonia aculeata, and Prosopis dulcis. Some of the Bursera trees are evidently B. malacophylla, an endemic species collected on the Seymour Isands some years ago by Snodgrass and Heller, but whether or not they were all of this species could not be determined as the Bursera trees were in the resting condition both times this island was visited by our party. A few dried leaves was all that could be obtained of this species.

There is a small salt-water lake near the west side around which there are a few small trees of Avicennia officinalis. Mangrove swamps are probably present along the shore of the channel separating the island from Indefatigable, but as they were only seen from a distance the extent and composition of them could not be determined. Goats have been introduced upon this island during the past few years, by the inhabitants of one of the other islands. They manage to gain a miserable existence from the scanty vegetation and render the island even more barren than it would otherwise be.

North Seymour is next in size to South Seymour. It is apparently covered with a dense growth of Croton, and other bushes. The middle island is low and small. There were large red-colored patches of vegetation on it which had the appearance from a distance of being composed of Sesuvium Edmonstonei.

Tower Island.

This is one of the smaller islands which lies about twenty-eight miles east of Bindloe. The shores are bordered by cliffs about forty feet high on all sides except the south where there is a small bay and sand beaches. The island is only four miles in diameter and is low in altitude, the highest point on it not being over 200 ft. above sea level. There is a crater, nearly a half mile in diameter near the center, but which can not be seen from the shore or from the surrounding ocean as there is no rim projecting above the surrounding country. There is a small salt-water lake at the bottom of this crater on the shore of which there is a grove of trees of Rhizophora Mangle. Small blow-holes occur at other places on the island.

Outside of the mangroves just mentioned, there are no other trees on the island except those of Bursera graveolens, which are small and heavily covered with lichens. Low thickets of Opuntia Helleri occur along the tops of the cliffs and for some distance back from them, and Cereus nesiticus is to be found in several isolated spots on the island. The most common bushes are those of Cordia lutea, Croton Scouleri, Lantana peduncularis, and Waltheria reticulata forma Andersonii. A few grasses, sedges, and other herbaceous plants have been reported from this island, but as our party visited it during the dry season in September, none of these were found.

Wenman Island.

With the exception of Culpepper, Wenman is the most northern island of the group. It is nothing more than an immense rock, about a mile in diameter, which lies seventy six miles northwest of Abingdon Island. The main island is surrounded by perpendicular cliffs on all sides but the north where they are somewhat broken down so that a landing can be effected and the upper part reached. In many places the cliffs are several hundred feet high, and some of them reach practically to the highest part which probably has an elevation of about 800 ft. There is a smaller island, to the north of the main one, and separated from it by a narrow channel. This, however, was not visited by our party. The channel between the islands is comparatively shallow and it is likely that an anchorage could be made here. It was not attempted by our party.

We were unable to remain on this island for more than a few hours in consequence of this the higher parts were not visited, botanical collecting being confined to a shelf about 250 ft. above sea level. The remainder of the island rises several hundred feet higher.

The only trees found on the island were those of Erythrina velutina, a small grove of which occurs on the northeast side. Bushes of Croton Scouleri var. brevifolius occur in dense thickets and some of the specimens are several feet high approaching the size of small trees. Low thickets of Opuntia Helleri are to be found along the tops of the cliffs and hanging over the sides. Ipomoea Kinbergi occurs commonly on trees. Other plants found rather abundantly are: Scalesia Snodgrassi, and Telanthera Helleri var. obtusior. A few ferns were seen growing in inaccessable places on the sides of the cliffs. By shooting into a bunch of these enough material was brought down to show that Nephrolepis biserrata occurs here, but whether or not there are any other species of ferns can not be said. The small island, to the north of the main one, appeared to be covered with Croton, and other bushes.

SOME OBSERVATIONS CONCERNING THE BOTANICAL CONDITIONS ON THE GALAPAGOS ISLANDS.

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